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VARICOCELE OF THE BROAD LIGAMENT

A venographic study

by

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We have succeeded in demonstrating varicocele of the broad ligament by means of retrograde pelvic venography in a relatively large material and since this appears to be a new method of diagnosing the condition we believe there is justification in reporting our findings. We shall confine ourselves in the main to the diagnostic considerations and not deal with the clinical signs and treatment.

An anatomical account of the pelvic blood vessels by FARABEUF (1905) contains a drawing of the periuterine veins in an injection specimen from the corpse of a 70-year-old multipara. It shows a greatly enlarged vein passing along the left border of the uterus and constituting a direct communication between the dilated uterine and ovarian veins. This was unquestionably a case of varicocele of the broad ligament, but at that time the condition had not engaged the attention of gynecologists. Varicose veins around the uterus and ovaries have since been observed in the course of operations. It is thought that pain may result from these varices when the patient is standing, but subsides when she is recumbent (CASTAÑO; LAGO; MATTSON). Surgical methods of removing the varices or of inducing their collapse have been reported; according to MATTSON, the pain disappears after such operations. These dilated

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veins are difficult if not impossible to detect prior to an exploratory operation (EMGE).

Little is known about the etiology of varicocele of the broad ligament. In the opinion of FEGERL & NARIK the condition occurs chiefly in women who have borne children. FAGARASANU, who has made a careful anatomical study of the ovarian veins and their relations to the vena cava, considers that the varices arise because the left renal vein is sometimes without collaterals; hence stasis occurs where the vein crosses in front of the aorta.

Methods and Anatomy

The venographic method employed in this study has been described earlier (HELANDER & LINDBOM 1955). A polythene catheter was introduced percutaneously into each of the femoral veins, the tip being placed in the external iliac vein approximately where the latter joins the internal iliac vein. The inferior vena cava was totally compressed and 30 ml of 30 % tri-iodo water-soluble contrast medium was injected on either side at the rate of approximately 8 ml per second. The contents of the iliac veins increased rapidly with this procedure and the venous valves in the cranial part of the thigh closed. During the continued injection in this closed venous region, consisting of the distal part of the vena cava and the external and common iliac veins bilaterally, the contrast medium was in most cases able to escape only through the internal iliac veins, passing retrogradely into those vessels, and thence via the presacral and sacral veins up through the azygos to the lumbar veins. In about half the cases studied it was possible to observe valves in each of the internal iliac veins at a depth of approximately 5 cm, these preventing further descent of the contrast medium into the pelvic veins. In another one-third or more of the cases, the medium injected was arrested at the same level in the internal iliac veins although no valves were discernible in the films; functioning valves were probably present in those cases also. The contrast medium in about 15 per cent of the cases passed the usual sites of valves and descended into peripheral pelvic veins to outline the utero-vaginal and vesical plexuses and frequently the ovarian vein as well, thus permitting the examination of those vessels (Figs. 1 to 4).

Material

Three hundred women, only a few of reproductive age, were examined by this method. The majority had carcinoma of the cervix, though other conditions were included in the series. Thirty-eight cases showed contrast

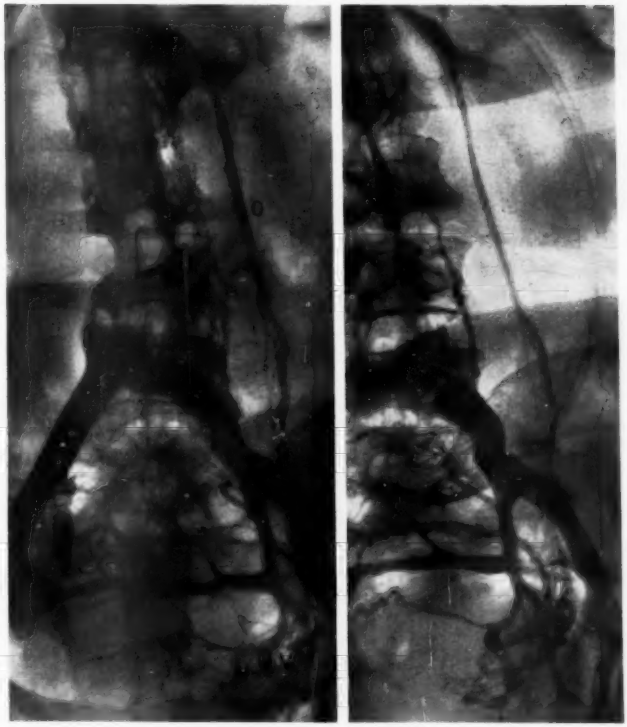

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Fig. 1. Retrograde pelvic venography with filling of left utero-vaginal (UV) plexus and left ovarian vein (O). Veins moderately dilated. a) A.p. view, and b) oblique.

filling of the utero-vaginal plexus and ovarian vein either unilaterally or bilaterally, and were subjected to further study. The veins of the utero-vaginal plexus were in some of them dilated, with one large vein forming a fairly direct communication between the uterine and ovarian veins (Fig. 4). The diameter of this vein could be measured approximately and in 17 cases was found to exceed 0.5 cm. Since such large veins are seldom observed at gynecologic operations on non-pregnant women we have chosen to designate them as varices; and these 17 cases represent our series proper of varicocele of the broad ligament.

Eight of the 17 cases were detected incidentally in a series of cervical carcinoma cases which, prior to treatment, had been examined for the

purpose of revealing metastases causing deformities of veins along the pelvic walls. The incidence of varicocele is unlikely to be higher in carcinoma than in other cases; hence the present figure of about three per cent may be approximate to the general incidence.

In 2 cases the venographic findings were verified at operation, and in 2 others distended veins were observed at culdoscopy. The 21 cases with retrograde contrast filling of non-varicose pelvic veins included two sisters with congenital, probably hereditary, general absence of venous valves (LODIN et coll.).

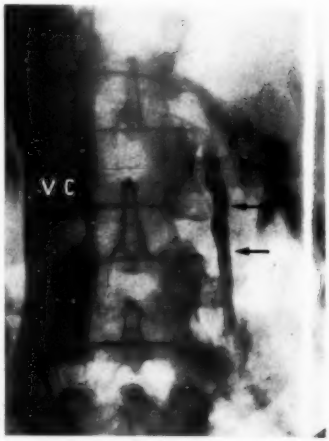

Fig. 2. Same case as in fig. 1. Filling of cranial part of left ovarian vein (arrows) by injection into left renal vein through a hooked catheter introduced percutaneously into left femoral vein. Film obtained at the end of a forceful injection; tip of catheter was placed in renal vein at start of injection but has just slipped up into vena cava (VC).

Venographic findings

Where filling of the utero-vaginal plexus occurred, the contrast medium passed retrogradely through an internal iliac vein beyond the site at which valves usually prevent its descent into the pelvic veins. This particular contrast filling was in 21 cases found only on the left side (Fig. 1), in 7 cases only on the right side (Fig. 3), and in 7 others it was bilateral (Fig. 4). The flow from the pelvic veins in most cases still passed via the left ovarian vein even when the contrast medium descended into the right internal iliac vein; in these cases the medium crossed the midline via the veins of the uterus and around the urinary bladder (Fig. 3). The right ovarian vein was filled only in 8 cases, far less frequently than was the left. In 1 case the left ovarian vein had the character of a venous plexus, in 2 it was duplicated, and in the others it was for most of its length a single vessel. The diameter of this vessel was measurable in 30 of the cases; it varied in the roentgenograms at the level of the third lumbar vertebra between 2 and 12 mm but was usually 5 to 7 mm. There was no appreciable correlation between this diameter and the patients' ages or the number of children they had borne. In the 17 cases of varicocele the ovarian vein was of a greater mean diameter than in the other cases.

In each of the two cases without valves we observed good contrast filling of the utero-vaginal plexus bilaterally and also of the left ovarian vein. In most cases in which the ovarian vein was outlined the inferior vena cava was also examined venographically in conjunction with the

pelvic venography and showed no stenosis or obliteration. In one case, in which at retrograde pelvic venography a cranial flow of contrast medium into the left ovarian vein was observed, a curved polythene catheter was introduced percutaneously into the left renal vein and contrast medium rapidly injected. Some of the medium descended through the ovarian vein (Fig. 2).

Etiologic considerations

The flow from the pelvis may proceed in some cases partially via venous plexuses in and around the uterus and by the ovarian vein when the inferior vena cava is compressed. Retrograde flow through the internal iliac vein into the utero-vaginal plexus is more common on the left than on the right side. The difference in retrograde flow on the two sides may be attributable to the fact that with our technique the right ovarian vein is often compressed at its junction with the vena cava and thus the flow from the right half of the pelvis is probably restricted, by comparison with the left side where the ovarian vein remains open. However, in most of our cases in which the contrast medium descended solely on the left side, functioning valves were detectable in the right internal iliac vein. It thus seems that the insufficiency or aplasia of the valves of the internal iliac vein, which is the condition required for contrast filling, is in fact more common on the left than on the right side. We can offer no explanation of this finding.

One of the patients with contrast filling of both ovarian veins had had thrombosis of the left leg following childbirth seven years previously; she showed a typical post-thrombotic deformity of the recanalized left external iliac vein and total obliteration of the ipsilateral internal iliac vein. The veins of the utero-vaginal plexus, which in this case were filled from the right internal iliac, were not dilated, and it appeared likely that the ovarian veins had served as collaterals at the time of the thrombosis and had continued to function as such. In the other cases of varicocele no post-thrombotic deformation of pelvic veins could be discerned, and both the left and right internal iliac veins showed regular lumina. There is in this series therefore no evidence that earlier thrombosis may be a common cause of dilatation of the veins and of return flow through the ovarian veins.

The two patients with no venous valves in whom retrograde contrast filling of the utero-vaginal plexus and the ovarian veins was obtained differed in several respects from the others. These two sisters had suffered from chronic leg ulcers since the age of 16 and, unlike the other cases, they showed retrograde contrast filling of the gluteal and lumbar veins. This anomaly is probably an uncommon one. In none of our varicocele

Fig. 3. Retrograde filling of uterine veins (arrows) from the right internal iliac vein. The contrast medium flows through the uterine veins to the left side and escapes to the left ovarian vein (O).

Fig. 4. Retrograde filling of peripheral pelvic veins bilaterally. Moderately dilated utero-vaginal veins on the right side. Large direct venous connection (arrow) between left internal iliac and ovarian (O) veins. Varicocele of broad ligament.

cases had there been ulcers of the leg. It seems unlikely therefore that this unusual condition of absence of venous valves may cause varicocele of the broad ligament except possibly in rare cases.

According to TOPOLANSKI-SIERRA, varicosities often develop in the uterine or ovarian pedicles in cases of chronic infections. Of the 36 cases remaining in the series, after exclusion of those without valves, there were 2 which had had verified salpingitis. One of them had undergone bilateral salpingectomy about 20 years prior to the pelvic venography; the other had acute bilateral salpingitis at the time of examination. Salpingitis or some other inflammatory condition of the pelvic organs may possibly have been present in a few other cases, but the great majority had no history of any such condition. Inflammatory conditions are therefore not likely to be a common cause of varicocele of the broad ligament.

Some authors have observed that most women with varicocele of the broad ligament are parous. All of our patients had borne children and most were multiparae. The mean number of children in the 36 cases

(t 2 without valves excluded) was 2.9, and in at least three cases there h been twins. HODGKINSON, who measured the average caliber of the o rian vein during operations, found an outer diameter of 25.9 mm in p gnant and 9 mm in non-pregnant women. It seems plausible to assume tl the uterine vein varies to the same degree. Valvular insufficiency m perhaps develop at the junction of the internal iliac and uterine v s in connection with the substantial changes in diameter which are a ciated with pregnancy; it is well known that varices of the legs are fr quently aggravated in pregnancy. The same factors that produce such v ices may possibly affect the pelvic veins as well. Although a causal re tionship may exist between pregnancies and varicocele of the broad li ment, no conclusive evidence of this can be found in the present series.

BORELL & FERNSTRÖM have shown that an arterio-venous shunt m y occur in placental necrosis associated with pregnancy. In this condi on the parametrial veins are greatly dilated and it is perhaps possible th t the dilatation may remain when the shunt is no longer present. In our cases however, no direct support has been found for such an explanation.

Another consideration worth noting here is that EDSMAN, in an extensive series of renal aortographies, observed frequent filling of the left ovarian vein in the venous phase; the contrast medium passed from the left renal into the ovarian vein, flowing in a caudal direction. This was seen only in females. We ourselves have made similar observations in aortographies. A caudal flow in the ovarian vein was detected in one of our cases upon injection of contrast medium directly into the renal vein (Fig. 2). It thus appears that in varicocele of the broad ligament the blood in the left ovarian vein may flow caudally, i. e. in the direction opposite to that considered normal. In retrograde pelvic venography therefore, the direction of flow in the ovarian vein may be temporarily reversed. As to the cause of this retrograde flow in the left ovarian vein, we hesitate to express a definite opinion. One conceivable explanation lies in FAGARASANU's hypothesis of stasis in the left renal vein where it passes in front of the aorta; another possible explanation is valvular incompetence at the opening of the left ovarian into the left renal vein, associated with pregnancy.

Varicocele of the broad ligament is a condition that is difficult to diagnose. The procedures now available for establishing its presence are culdoscopy and the venographic method described. In culdoscopy, only a limited area is accessible to inspection, and it is not easy to judge the degree of enlargement of the veins, whereas retrograde pelvic venography affords a good survey of the veins on both sides, and the degree of dilatation can be evaluated. It seems to us, therefore, that our method is the more satisfactory one for revealing the condition.

SUMMARY

Varicocele of the broad ligament is a not uncommon condition and may be diagnosed by means of retrograde venography. The etiology is discussed.

ZUSAMMENFASSUNG

Varicocele im Ligamentum latum sind nicht ungewöhnlich und können durch retrograde Venographie diagnostiziert werden. Die Äthiologie wird diskutiert.

RÉSUMÉ

Le varicocèle du ligament large n'est pas une affection exceptionnelle et peut être diagnostiqué par phlébographie rétrograde. Les auteurs étudient son étiologie.

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ARTERIAL MALFORMATION IN THE SUPERIOR MEDIASTINUM

by

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In recent years the treatment of congenital anomalies of the great vessels has acquired an important position in thoracic surgery. This, although due primarily to the great advances in surgical technique, owes a good deal to improved means of pre-operative diagnosis, particularly within radiology. Venous and selective angiocardiography as well as thoracic aortography now permit a detailed elucidation of the nature of the anomalies of the great vessels in the superior mediastinum. These vessels may in various ways compress the trachea and/or the oesophagus, giving rise to stridor and/or dysphagia.

A total of 20 cases of vascular anomalies in the region of the aortic arch have been diagnosed during the past years in the author's hospitals. Seven were treated by operation.

The aortic arch is formed during the 3rd to 6th embryonic week from the left fourth branchial arch. The right third and fourth branchial arches and the left third arch become the great arteries arising from the aortic arch. If this development does not take place, a number of vascular

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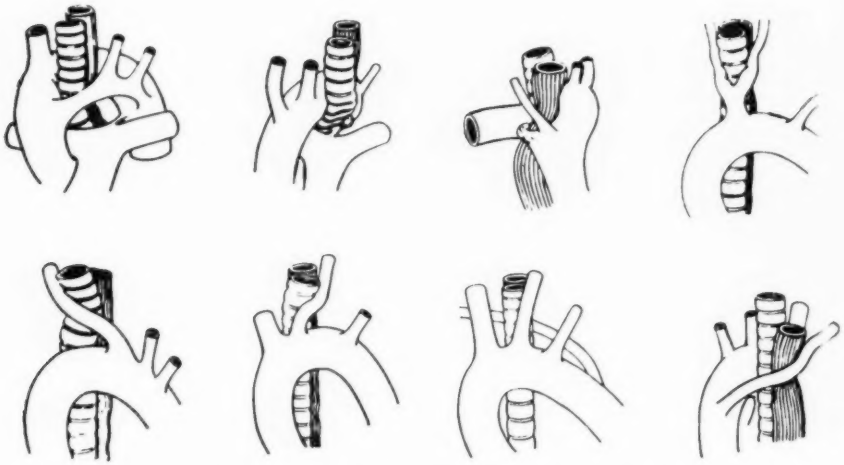

Fig. 1. Schematic representation of the most common vascular anomalies giving rise to compression of the oesophagus and/or trachea. (After R. E. Gross.)

anomalies may arise, some of which may cause compression of the oesophagus or trachea, or both, and thus acquire clinical significance.

According to Gross (Fig. 1) the most important vascular anomalies are as follows:

1. A double aortic arch forming a complete vascular ring around the trachea and oesophagus. As a rule, the posterior arch is larger, i. e. there is a large aortic arch, coursing to the right of the trachea, then behind it and the oesophagus towards the left, but finally less to the left in the chest than a normal aorta. In front of the trachea and oesophagus there is a smaller arch, connecting the ascending and descending aortae.

2. A posterior aortic arch and a ligamentum arteriosum, together forming an incomplete ring around the trachea and oesophagus.

3. Lastly, there may be an anomalous origin and course of the great arteries from a normally coursing anterior aortic arch, the right subclavian artery frequently arising from the descending aorta.

The first signs of a compressing vascular ring appear shortly after birth. A characteristic sign is stridor accompanied by attacks of cyanosis, usually elicited by feeding. Due to the oesophageal compression, the food may pass up from the oesophagus and down into the trachea.

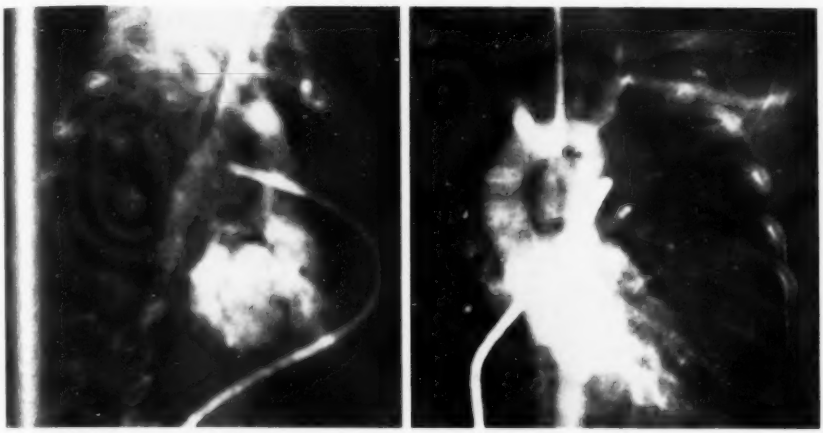

Fig. 2. Angiocardiogram showing a small aortic arch behind the trachea and oesophagus (at the tip of the catheter inserted into the oesophagus) and a large anterior arch.

resulting in asphyxia and recurrent attacks of pneumonia. In the most severe cases there is persistent inspiratory and expiratory stridor with retraction of the intercostal muscles and neck on inspiration; the patient will assume a hyperextended position, straightening out the trachea to improve the passage of air. In other cases, the vascular rings and anomalous vessels produce only slight or no signs, and the diagnosis is generally not made until autopsy, or is a chance finding in a roentgen examination of the oesophagus.

Endoscopy (laryngoscopy, bronchoscopy, or oesophagoscopy) seldom reveals the nature of the condition. Postero-anterior and lateral views of the chest may possibly reveal a forward displacement and an indentation of the trachea. Roentgen examination of the oesophagus will reveal narrowing of the lumen from behind and a forward displacement at the level of the third or fourth dorsal vertebra. Lastly, the diagnosis may be confirmed by angiocardiography and aortography (Fig. 2) which permit determination of the accurate position of the anomalous vessels.

Our material comprises 20 patients, 16 of whom were children under 12 years of age, 14 females and 6 males. Seven underwent operation.

The seven operated patients with vascular malformations in the superior mediastinum were infants (aged between 3 and 20 months). The operative indications were based primarily on the clinical condition. Five had a complete, and one an incomplete ring, while one had an abnormal course of the innominate artery which greatly constricted the trachea. Brief case reports of the seven cases subjected to operation are presented below and illustrated in Fig. 3.

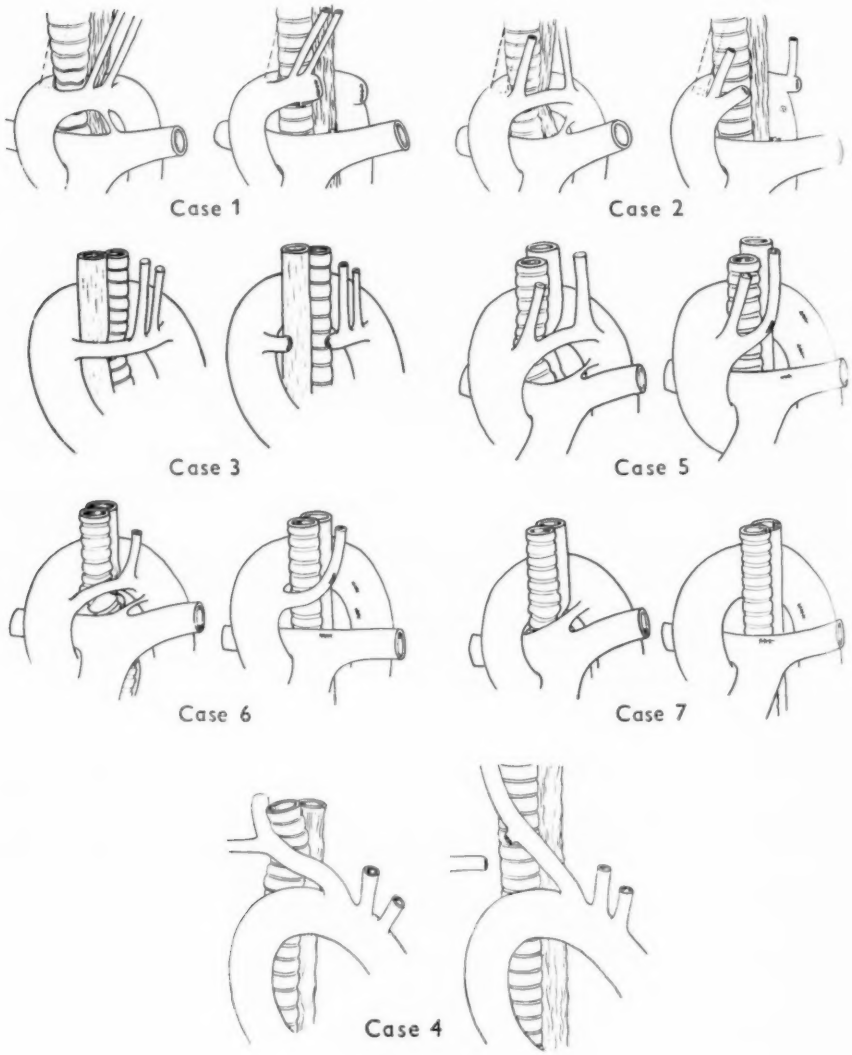

Fig. 3. Schematic illustrations covering Cases 1 to 7 and showing the different operative findings and the vascular resections performed.

Case 1. Girl, aged 3 months, with stridor, attacks of cyanosis and dysphagia. *Roentgen findings:* Narrowing, and displacement of the oesophagus. Operative findings: Complete vascular ring with equally large anterior and posterior aortic arch. The anterior arch to the left of the left subclavian artery and a patent ductus arteriosus were resected.

Case 2. Girl, aged 5 months, with stridor, cyanosis, dyspnoea, regurgitation, and syncopal attacks. *Roentgen findings:* Concentric narrowing of oesophagus. Operative findings: Complete vascular ring with large posterior and small anterior aortic arch. The latter was resected between the subclavian artery and the left common carotid artery. Resection of patent ductus arteriosus.

Case 3. Boy, aged 5 months, with stridor, cyanosis, dyspnoea, and vomiting. *Roentgen findings:* Concentric narrowing of oesophagus and indentation posteriorly; compression of trachea. At angiocardiography: anomalous posterior vessel (see Fig. 2). Operative findings: Complete vascular ring from behind; large anterior, and small posterior arch from which arteries arose. Right-sided incision with resection of the posterior arch on the left of the right subclavian artery and the right common carotid artery.

Case 4. Girl, aged 6 months, with sequelae of oesophago-tracheal fistula, attacks of cyanosis, regurgitation and dyspnoea. *Roentgen findings:* Narrowing of trachea and oesophagus. Operative findings: Abnormal course of innominate artery which was pulled backwards by the right subclavian artery, compressing the trachea. The right subclavian artery was resected.

Case 5. Boy, aged 6 months, with stridor, cyanosis, syncopal attacks and bronchitis. *Roentgen findings:* Posterior indentation and displacement of the oesophagus; trachea narrowed. Operative findings: Complete vascular ring. Resection of the anterior smaller arch on the left of the left subclavian artery which ran an oblique course across the trachea without compressing it.

Case 6. Girl, aged 12 months, with stridor and recurrent bronchitis. *Roentgen findings:* Oesophagus much narrowed; tracheal indentation. Angiocardiography showed a right-sided aorta with double arch. Operative finding: Complete vascular ring. Resection of the anterior smaller arch close to the descending aorta to the left of the left subclavian artery. Resection of patent ductus arteriosus.

Case 7. Girl, aged 20 months, with mild dyspnoea during the five first months. Systolic murmur. *Roentgen findings:* Concentric narrowing of oesophagus and posterior indentation. Operative findings: Incomplete vascular ring, the aortic arch lying behind the oesophagus. Compression by patent ductus arteriosus which was resected.

Among the 13 patients who did not undergo operation, three had mild symptoms of tracheal compression with exertional dyspnoea, five presented symptoms due to other conditions, and five were asymptomatic. The three patients with mild symptoms at the time of the study had earlier had marked dyspnoea and stridor but no dysphagia. Among the asymptomatic cases the arterial malformation was a chance finding during roentgen investigation of the oesophagus, but two of them had previously had signs of tracheal and oesophageal compression. Eight patients (four children and four adults) had never had any symptoms suggestive of tracheal or oesophageal compression. The children were examined because of abnormal findings upon auscultation of the heart. In the four adults the vascular anomaly was a chance finding during examination for other diseases. Indeed, one of the patients had reached the age of 64 years without ever having suffered from stridor or dysphagia (Fig. 4).

In all cases of this group, roentgen examination of the oesophagus revealed an indentation of the lumen, often coexisting with displacement. In some cases, an examination of the oesophagus will enable a distinction to be made between a vascular ring and an anomalous subclavian artery (NEUHAUSER), as in the latter condition there is often a narrow oblique indentation of the oesophagus and in the former a more marked forward displacement. The indentation and the displacement of the oesophagus were marked in nearly all the cases, whether they had no symptoms, mild symptoms, or symptoms so severe as to necessitate operation. Narrowing of the oesophagus per se is therefore not a sufficient indication for surgery.

Compression of the trachea, more or less marked, was present in four cases.

Some of our non-operated patients probably had anomalous subclavian arteries, but frequently the appearances of the oesophagus are so uniform that the correct diagnosis has to await aortography. Aortography was only performed in five cases of this group. In four cases anomalous arteries from the aorta and in the fifth case a posterior arch were demonstrated.

According to the literature, a double aortic arch is fairly rare. NEUHAUSER (1946) has reported 4 cases, 2 of which had been operated upon by GROSS, who published the first operated case in 1946. GORDON (1947) collected 11 cases, including 4 of his own. The largest material has been reported by GROSS, i. e. 70 cases of vascular malformation in the mediastinum with signs, including 26 with double aortic arch. THOMSEN, HUSFELDT & VESTERDAL (1953) reported 3 cases, one of which was of a double aortic arch and two of anomalous subclavian arteries without signs. EKSTRÖM & SANDBLOM analysed 83 cases from the literature

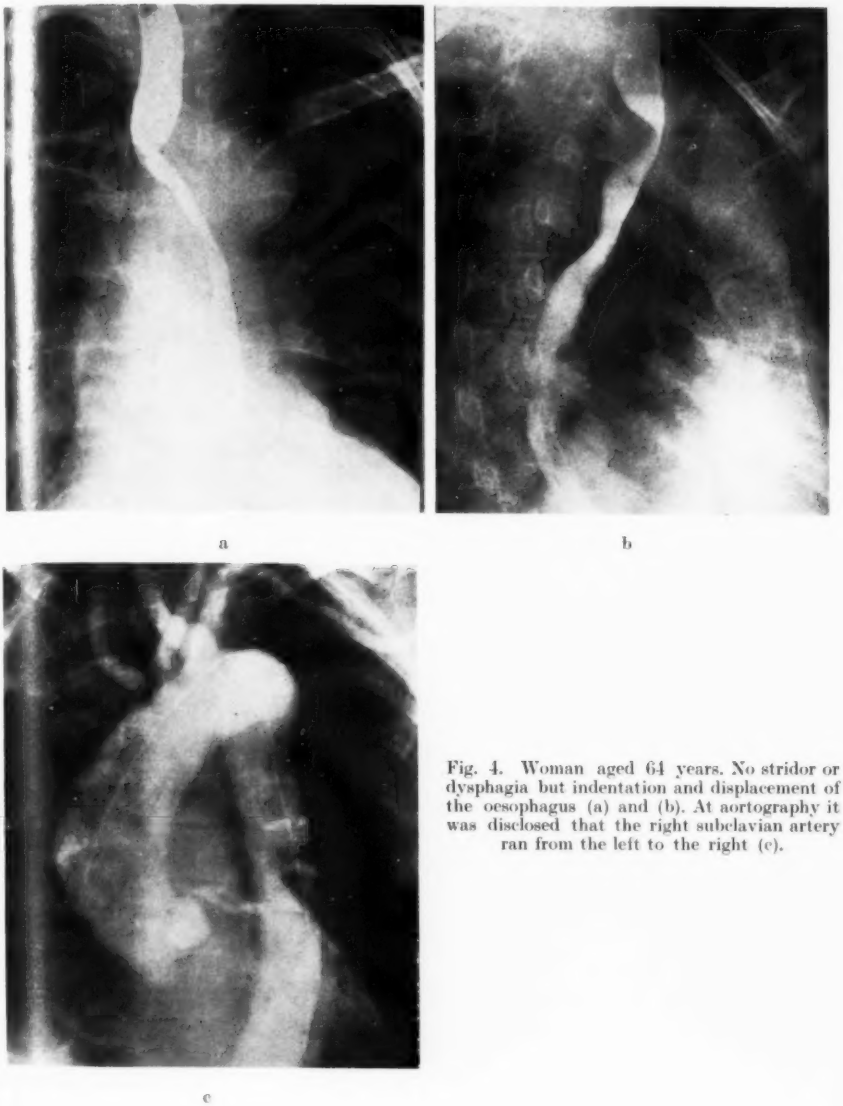

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Fig. 4. Woman aged 64 years. No stridor or dysphagia but indentation and displacement of the oesophagus (a) and (b). At aortography it was disclosed that the right subclavian artery ran from the left to the right (c).

and added two operated cases of double aortic arch of their own. Like Gross, they concluded that infants with marked signs would die if not subjected to operation.

KJELLBERG et coll. report 3 operated cases with typical vascular rings (one had previously been reported by SANDBLOM & EKSTRÖM). According to these authors, thoracic aortography is often useless, since a portion of the ring may consist of fibrous remnants of the previous vessels (lig. art.) not demonstrated by ordinary aortography.

An effort is made at operation to relieve the compression of the trachea and oesophagus by resecting the thinnest and most accessible vessel of the ring.

SUMMARY

The diagnosis and treatment of the different forms of vascular anomalies of the great arteries arising from the aorta are discussed. The material consisted of 20 cases, 7 of which were subjected to operation.

ZUSAMMENFASSUNG

Die Diagnose und Behandlung der verschiedenen Formen vasculärer Anomalien der grossen Aortaäste werden besprochen. Das Material bestand aus 20 Fällen, wovon 7 operiert wurden.

RÉSUMÉ

Les auteurs étudient le diagnostic et le traitement de différentes formes d'anomalies vasculaires des grandes artères provenant de l'aorte. Les cas étudiés sont au nombre de 20 dont 7 ont été opérés.

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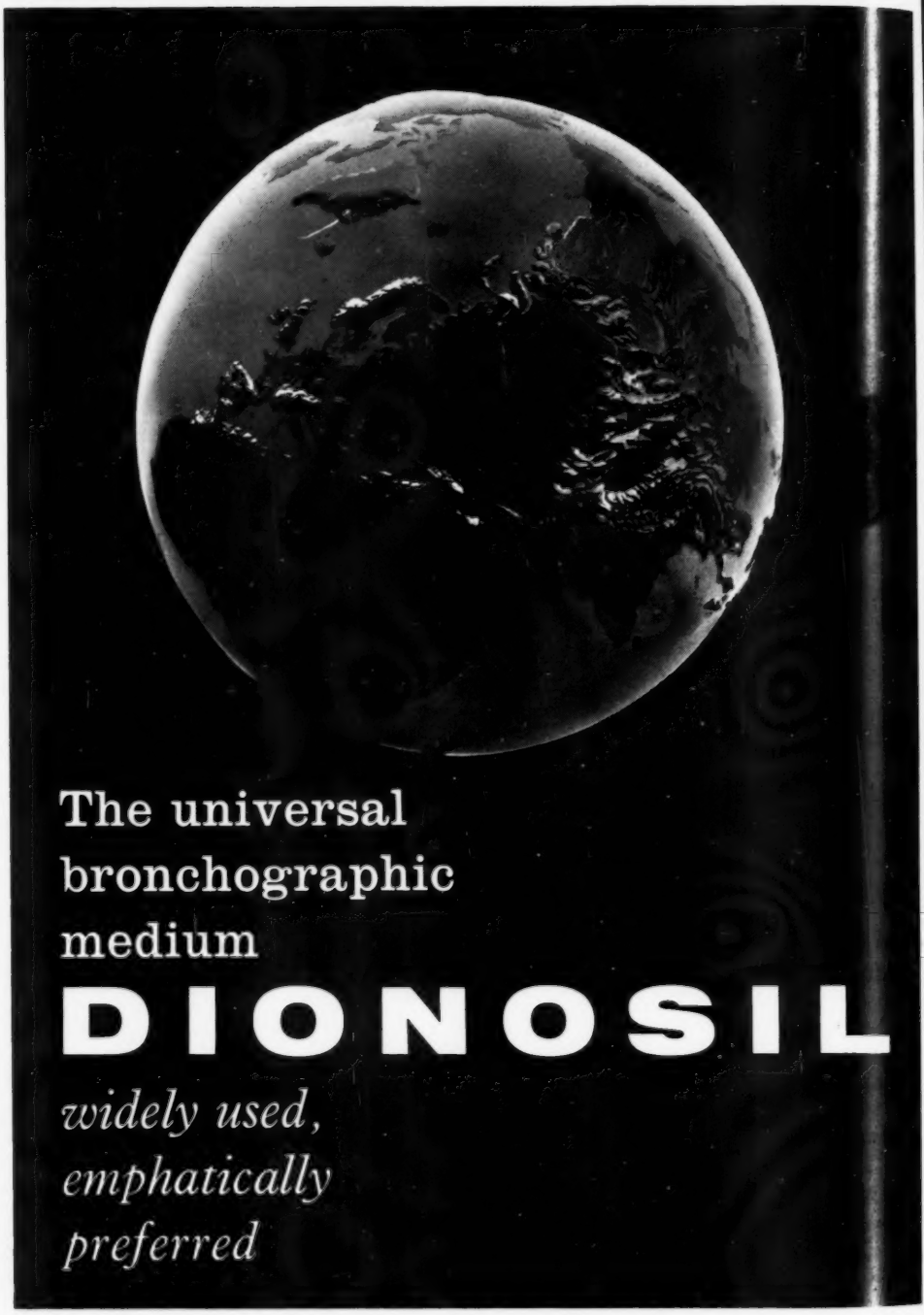

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BURLINGTON, VERMONT, U. S. A.

THE VALUE OF ROUTINE LATERAL RECTAL PROJECTION IN BARIUM ENEMA STUDY

by

Henry C. Forrester and *A. Bradley Soule*

It has often been said that the radiologist need not concern himself with detailed or special examination of the rectum and pelvic sigmoid colon, since this area is within easy reach of the gloved finger or sigmoidoscope and should naturally be relegated to the attention of the experienced proctologist or surgeon. This statement, of course, assumes that every patient with lower bowel symptoms has had such an examination performed by a competent observer, and the lesion, if any, discovered and diagnosed; the barium enema study then is primarily directed toward ruling out other abnormalities in the more proximal portions of the colon.

However, such an assumption is not only dangerous but foolhardy as well. Numerous cases have been reported where rectal or sigmoidoscopic examination has been performed with negative results, only to have small lesions, such as polypi or early carcinomas, appear in the rectum or rectosigmoid colon on roentgen examination. Also, in the radiology department of an average general hospital, patients are referred from heterogeneous sources so that one cannot depend on the rectal or sigmoidoscopic examination as having been done, even though the patient may present lower bowel symptoms. In some clinics, all patients referred for enema study routinely have sigmoidoscopic or proctoscopic examination

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performed in conjunction with the barium studies. This is, of course a highly commendable procedure and one which should be more generally accepted; however, it is also a factor which may lull the radiologist into a false sense of security about an area of the colon which comes directly under his scrutiny and responsibility once the barium enema study is begun. The radiologist frequently has a better opportunity to appreciate any abnormal changes which may have occurred in the supporting tissues of the pelvis, as they relate to rectal or sigmoid mobility and filling, than has the proctologist or surgeon who is limited to what can be appreciated from his examination by varying lengths of rigid pipe. Since the distal colon and rectum are the sites of over 75 % of all cancers of the entire large bowel and are quite complicated anatomically, it behooves us to make every possible attempt at early and accurate diagnosis by whatever means available. The value of the lateral rectal projection has been demonstrated by others in the past, and this view should be used in every barium enema examination. We are of the opinion that it provides considerable information to the radiologist regarding the condition of the upper rectum and rectosigmoid.

As has been stated by WELIN, the routine barium enema study can no longer be considered adequate for examination of the colon in view of the excellent demonstration which may be obtained by routine air-contrast technique following complete cleansing of the bowel using special astringents. This statement probably does not apply as strictly to intraluminal defects, as produced by malignant neoplasms, as it does to the detection of polyps, and further implies that sufficient time, experience, technical help and equipment are available to make the routine use of air-contrast study feasible. While there is no doubt that this method provides a superior means of studying the colon, it would seem that practicality will limit its general use to those cases where colonic polyps are suspected or have been previously demonstrated. Because the routine barium enema study will continue to be the busy radiologist's mainstay for some time to come, we undertook a separate study to determine what optimum technical factors should be employed and which barium-water mixture should be used to provide the best visibility of a simulated rectal polyp.

A 1.5 cm diameter paraffin ball which roughly approximates the density and atomic number of soft tissue was suspended in the center of an 8 cm column of barium within a waxed paper container; this in turn was placed in the center of an infinite presdwood phantom measuring 35 cm in height, and the small air spaces between the cup and board edges were filled with a rice-floor mixture. It was then possible to obtain roentgenograms of the 'polyp' within the phantom which would correspond quite closely to the conditions present when taking the routine lateral projection after the bowel has been filled with barium. These conditions

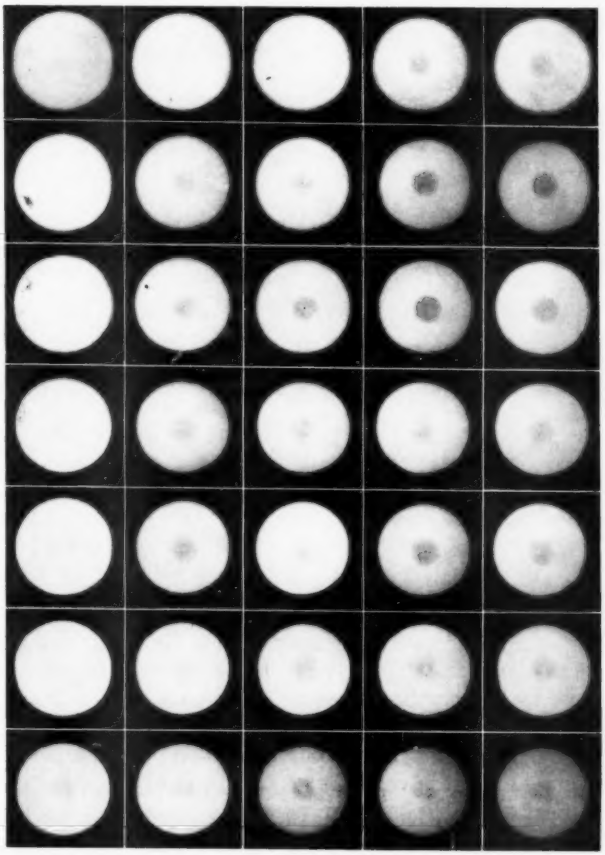

Fig. 1. A composite photograph of presdwood phantom studies. Kilovoltage varies from 75 to 130 kV from left to right (75, 90, 100, 120 and 130, respectively), and barium-water mixtures from 1:4 to 1:10 from top to bottom.

were deliberately chosen because the tissue thickness, the dense barium collection and the complete surrounding of the 'polyp' would provide the most unfavourable conditions for detection of a simulated polyp. In addition, it would also be possible to correlate the phantom results with actual patient study. Various barium-water mixtures ranging from 1:4 to 1:10 by volume were then used and applied against kilovoltage settings varying from 75 to 130 kV with appropriate changes in the mAs factors to

Fig. 2. 120 kV, 50 mAs with 1:6 barium-water mixture. The paraffin ball in the upper rectum cannot be seen.

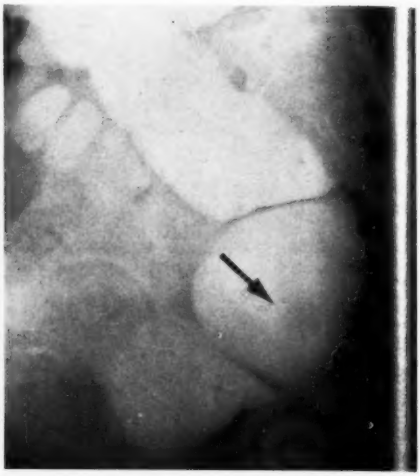

Fig. 3. 130 kV, 50 mAs with 1:8 barium-water mixture. The 'polyp' is only faintly visible.

maintain uniform background density. As is illustrated by Fig. 1, the phantom studies suggest that a mixture containing one part of barium to six parts of water, applied against potentials above 100 kV, provides the best differential contrast and visibility of the filling defect. The other factors used were 44″ (about 112 cm) TFD and 3 mm Al total filtration. Thicker barium mixtures tended to hide the 'polyp' particularly at the lower kV values while the thinner mixtures tended to lose considerable differential contrast particularly at the higher kV levels. This further suggests that the generally accepted use of high kilovoltage technique in polyp detection could be carried to disadvantageous extremes when using thin barium mixtures. After the phantom studies had demonstrated the efficacy of using high kV, low mAs factors at a 1:6 barium-water mixture, the same technique and the same paraffin ball, inserted into the upper rectum, were used in suitable patient studies.

Figs. 2 and 3 are roentgenograms of patients taken after insertion of the 'polyp' into the upper rectum, employing barium-water mixtures of 1:6 and 1:8, applied against kilovoltages ranging from 75 to 130 kV. It is painfully apparent that the polyp is only faintly seen at 130 kV, 50 mAs with the 1:8 mixture, and is otherwise invisible in the remainder of the series. These findings are at variance with the phantom studies previously presented, demonstrating the fallacy in direct application of phantom

Table

kV	mAs	TFD inches	TFD cm	Total filter mm Al	Dose in mr
90	200	33	83.8	1.5	900
90	200	33	83.8	2.5	760
90	200	31	78.7	2.5	840
95	150	33	83.8	2.5	670
100	100	33	83.8	2.5	600
90	200	33	83.8	3.0	680
100	100	33	83.8	3.0	580
90	200	36	91.4	3.0	640
100	100	36	91.4	3.0	520
75	400	44	111.7	3.0	600
90	120	44	111.7	3.0	565
100	100	44	111.7	3.0	445
120	50	44	111.7	3.0	315
130	30	44	111.7	3.0	210

result to clinical situations, even when the phantom is meticulously constructed. Radiologic physics predicts that an increased mAs exposure would eventually help somewhat in demonstrating the 'polyp' but at a probable prohibitive increase in the exposure dose delivered to the patient. It would seem therefore, that the physical conditions inherent to the profile view of the barium filled rectum make it unsatisfactory and unreliable for adequately detecting a free-floating polyp of the rectum, even at kilovoltages and total filtration beyond those generally employed, and that air-contrast study is essential for the diagnosis of lesions of this sort. The routine use of high kilovoltage technique in detecting polypi in other areas of the colon, particularly with compression or thin barium mixtures, undoubtedly has merit when properly employed, but the technique cannot be relied upon with any degree of certainty when studying the rectum or lower sigmoid colon, especially in the lateral projection.

Exposure dose

The advantages of using high kilovoltage, low milliampère-second technique are not limited entirely to a better demonstration of polypi but are also critical in reducing the exposure dose delivered to the patient during radiography. Using small recently calibrated Landsverk ionization chambers, exposure doses were determined at depth in the same presdwood phantom employing various factors and filtration. The values obtained are listed in the Table above and would correspond closely to the dosages received by the female gonads when taking the lateral rectal projection. The male gonads in actual practice are coned outside of the primary

beam and receive mostly scatter exposure from the pelvic structures. Recent studies (ARDRAN & CROOKS, WEBSTER & MERRILL) have shown that the male gonad dose received from the usual lateral view of the lumbar spine varies from 2.25 mr to 60 mr, depending on the factors and filtrations used. In studies previously reported from this institution (SOULE, HEILBRONN & BANNISTER), the total male gonad exposure dose received from a complete barium enema study in an adult is about 250 mr. This would include fluoroscopy totalling 3 minutes with 6.5 × 8.5 cm shutter size, five 6.5 × 8.5 'spot' films, four coned p. a. and oblique 14 × 17 films and two coned lateral views of the rectum before and after evacuation. It should be expected that the female gonad dose would be correspondingly somewhat higher.

We feel justified in suggesting that a projection which delivers relatively heavy radiation exposure to the pelvis be accepted as a routine part of the barium enema study. Since the vast majority of patients referred for barium enema are well beyond the childbearing age and this special projection is directed to an area which gives rise to a large percentage of all neoplasms, we believe that the returns well warrant the added radiation investment. In children and young adults, it would seem best, for the present time, to limit the use of the profile view to those cases where suspicions based on clinical or fluoroscopic evidence justify the risks of added gonadal exposure.

SUMMARY

The routine use of the lateral rectal projection in barium enema study has definite merit in detecting en face filling defects in the rectum and rectosigmoid, but the projection is unreliable for detection of free floating polypi of the rectum, even when employing high kilovoltage technique and thin barium mixture.

ZUSAMMENFASSUNG

Die routinmässige Anwendung der seitlichen Projektion bei Bariumeinlauf erwies sich zur Entdeckung von en face Füllungsdefekten im Rectum und Sigmoideum als ausgesprochen vorteilhaft. Diese Projektion ist jedoch zur Aufdeckung von frei flottierenden Polypen unvorteilhaft, auch wenn man Hochspannungstechnik und verdünnten Bariumbrei anwendet.

RÉSUMÉ

La pratique systématique de l'incidence de profil du rectum au cours des examens par lavement baryté présente un intérêt certain pour déceler les lacunes de face du rectum et du sigmoïde mais on ne peut se fier à cette incidence pour déceler les polypes rectaux flottant librement, même quand on utilise la technique à haute tension et des suspensions barytées diluées.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: GIOVANNI RUGGIERO) OF THE NEURO-SURGICAL CENTRE, STE ANNE HOSPITAL, PARIS, FRANCE

A TECHNIQUE FOR THE EXAMINATION OF THE OPTIC FORAMINA

by

Giovanni Ruggiero

HARTMANN has shown by anatomical investigations that the angle formed by the optic canal with the median sagittal plane may vary considerably with sex, and also at the two sides of the same skull, the average being about 35°, and that the angle formed with a horizontal plane through the nasion-inion line varies in a similar way, the average being about 31°.

Roentgenograms of the optic foramen are at present obtained mainly by two methods: (1) with the head kept straight and the central ray angled in two directions, and (2) with a vertical central ray and positioning of the head. Errors in centring are common with either method due to the anatomical variations mentioned, and due to the difficulty in determining symmetrical points of reference. If a skull unit is employed, however, correct centring seems to be easier with the former method, which is the one generally preferred by neuro-radiologists. An intermediate solution is obtained by means of an apparatus devised by BRUNETTI: the central ray is kept vertical and the film is inclined in relation to the fixed head.

According to our experience it is not easy with anyone of the recognized methods to obtain an absolutely reliable representation of the optic foramen.

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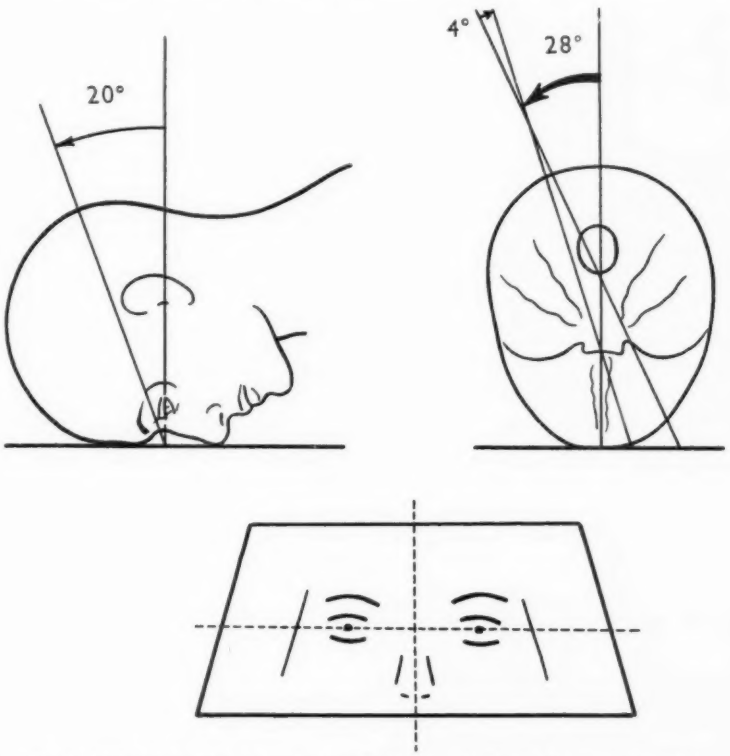

Fig. 1. Drawings showing the technique for the examination of the optic foramina.

The Hartmann technique. The patient lies prone with nose and chin on the film. The skull is covered with a close-fitting cap upon which two lines are embroidered; one line runs 7 cm forwards from the external occipital protuberance, the other at right angles to the first line and 6.5 cm to each side of its anterior termination. The terminal points of the second line indicate where the central ray should fall. As the tube is centred in the midline, the head must be inclined to either side, as required for the central ray to pass through the reference points. In children the reference points are altered by reducing the sagittal line to 6 cm and the halves of the lateral line to 5.5 cm. If the projection is correct, the optic foramen should appear in the infero-lateral quadrant of the orbit. If the foramen is projected too high, the forehead should be lowered and if too low it should be raised; if the foramen is displaced medially, the degree of rotation of the head should be increased, and if laterally it should be diminished.

It is claimed that this projection has two advantages: the central ray is directed perpendicular to the film, and a skull unit is unnecessary. We have, however, found that the risk of asymmetry due to technical

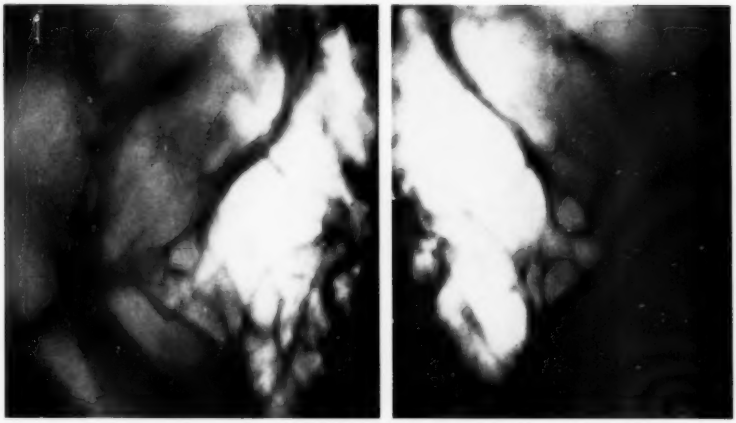

Fig. 2. Normal appearances of the optic foramina with the projections illustrated in fig. 1.

factors is considerable. A slightly different degree of pressure on the nose is sufficient to alter the axis of the optic foramen and the planes of the skull by several degrees and thus to make it impossible to compare the two sides.

The Brunetti technique. The apparatus consists of two boards joined along their long edges and inclined symmetrically so that they form an angle of 15° with the horizontal plane. The patient lies prone with the head straight between the boards, behind which the cassettes are attached. The tube is tilted in turn towards each board so that the central ray is projected at right angles to it and is automatically directed through the orbit by means of guide marks on a device between the boards.

This technique also possesses the merit that the central ray falls perpendicular to the film but the apparatus is unfortunately too heavy to be used in conjunction with a skull unit, and this latter provides many advantages, including the use of a secondary grid.

The Lysholm technique. The patient lies prone with the head on the skull unit which is self-centring. The head is positioned so that the cross in the mirror is seen over the inner canthus of the eye to be investigated, the orbito-meatal line being vertical to the table. The tube is angled 20° cranially and 20° towards the side not under investigation. The cassette is displaced 2 cm caudally and 2 cm towards the side to be examined. The secondary grid must be turned so that the slats lie in the same vertical plane as the central ray. An eccentric primary diaphragm is used. To be correctly projected, the optic foramen should be in the centre of the orbit and medial and inferior to the lesser wing of the sphenoid.

The advantage of this technique is the one common to all those in which a skull unit is employed, i. e. high precision in the directioning of the central ray. It appears however to offer certain difficulties in the

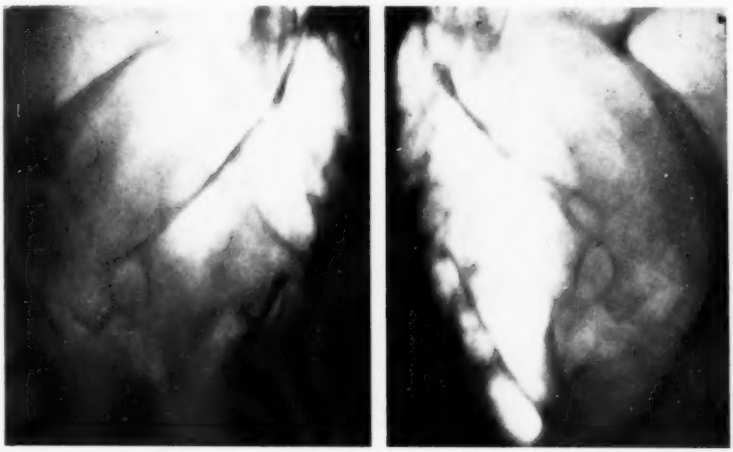

Fig. 3. Pituitary adenoma. The infero-medial contour of the right optic foramen is decalcified.

production of perfectly symmetric projections. The optic foramen often appears slightly oval on the film instead of round, and the images obtained with this projection are thus less reliable than those obtained with the Hartmann projection. The optic foramen seldom appears rounded, even if the lateral angle is increased up to between 25° and 28°, and furthermore the use of an eccentric diaphragm affects the quality of the roentgenograms. The Lysholm projection, however, affords a good demonstration of the bony septum between the optic foramen and the superior orbital fissure.

Author's technique

Because of the various drawbacks connected with the techniques most commonly in use up to now we have worked out another method which we have found satisfactory. This may be described as a modification of the Lysholm technique, though with some important differences. The preliminary positioning is the same with the exception that the cross is positioned on the midline between the two inner canthi. The central ray is then tilted through three angles; the first two are obtained by angling the arch of the skull unit 20° cranially and the tube 28° towards the side not under investigation. The third angle is obtained by tilting the tube laterally 4° towards the side to be investigated. The secondary grid is turned as previously, but a concentric primary diaphragm and a cone are

used. The head is kept in the same position, and when the first film has been obtained the optic foramen of the other side is investigated by turning the tube in the same way as for the first side examined (Fig. 1). Both the optic foramina are projected on to the same 18 × 24 cm film.

This method appears to possess all the advantages associated with the employment of a skull unit. The head has to be positioned only once for an examination of the two sides, which eliminates one uncertain factor. The angles given for the tube are based upon our own anatomical investigations. (The author is indebted to M. M. Millour for help in technical work.) The appearances obtained of the optic foramina more or less correspond with those obtained with the HARTMANN and BRUNETTI techniques.

SUMMARY

Various techniques for the roentgen examination of the optic foramina are reviewed. A method in which a skull unit is employed but in which the two sides are examined with the head fixed is described.

ZUSAMMENFASSUNG

Verschiedene Methoden zur Röntgenuntersuchung der Foramina optica werden durchbesprochen. Eine Methode, bei der ein Schädel-Untersuchungsgerät zur Anwendung kommt und beide Seiten bei fixierter Schädelstellung untersucht werden, wird beschrieben.

RÉSUMÉ

L'auteur passe en revue diverses techniques de radiographie des trous optiques. Il décrit une méthode utilisant un appareil de radiographie cranienne, mais dans laquelle les deux côtés sont examinés sans changer la position de la tête.

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EFFECT OF SECERGAN ON THE DUODENUM AND COMMON BILE DUCT

by

Paul Edholm

The effect on the duodenum and the common bile duct of a quaternary phenothiazine compound, secergan, has been studied roentgenologically. Secergan is a 10-(α-dimethylaminopropionyl)-phenothiazine methobromide and has an anticholinergic and ganglion-blocking action. It shows a marked spasmolytic effect on intestinal spasms and inhibits peristaltic movements (TOMENIUS 1957, WIELDING 1958). The drug is excreted via the bile and intestinal mucosa as well as the urine, as has been shown by ALLGÉN et coll. (1959) in studies on mice. Up to one hour after its subcutaneous injection a high concentration of the drug could be found in the liver, the gallbladder, the biliary ducts and in the small intestine near the orifice of the common bile duct.

Own investigation

The duodenum. The drug was tested during barium meal examinations. Twenty milligrams injected intramuscularly caused a cessation of all peristalsis in the duodenum and a widening of its diameter (Fig. 1). This effect was usually fully developed in five minutes. In some subjects the action of the drug was weaker and a few did not react at all.

It is sometimes difficult to obtain good filling of the duodenum due to the occurrence of spasm. The use of this drug was found to relax the spasm and produce informative films. Satisfactory filling of the duodenum may of course be of value for the examination of the pancreas.

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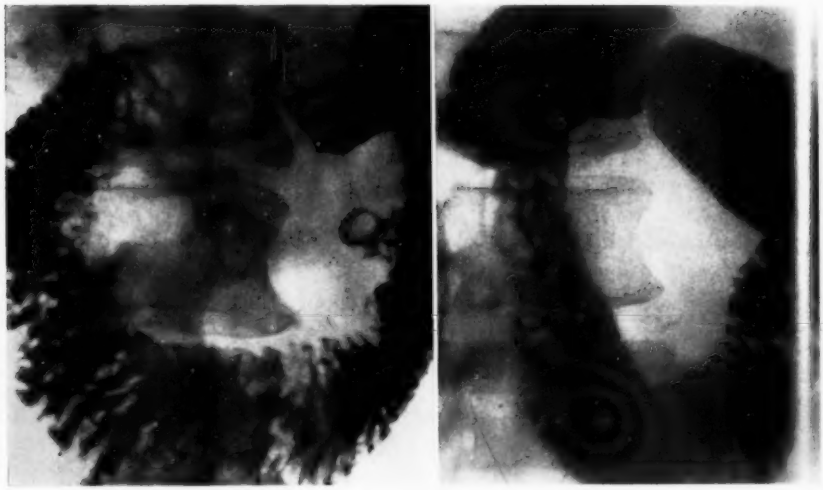

a b

Fig. 1. Two cases of duodenal spasm 5 min after intramuscular injection of secergan. a) Supine, and b) prone.

The common bile duct. The action of the drug was studied in cholegraphies as well as in operative and postoperative cholangiographies. In the last group, which comprised 9 patients, this was performed by cineroentgenography with the help of a screening system that combined an image amplifier and television, the image on the television screen being photographed by a 16 mm camera. Urographin 30 % was allowed to flow from a container 10 cm above the anterior abdominal wall, through the drainage tube into the common bile duct during the examination.

It was observed that the sphincter of Oddi contracted synchronously with the passage of a duodenal contraction over the region of the papilla. A few minutes after an intramuscular injection of 20 mg secergan was given, the activity of the sphincter ceased simultaneously with all duodenal peristalsis and the sphincter remained open. If the drug was given intravenously this effect was achieved in 20 to 30 seconds. It was found that morphine administered intravenously in doses of 1 to 3 mg restored the peristalsis of the duodenum after it had been inhibited by secergan. Secergan on the other hand could relax spasm of the duodenum and the sphincter induced by morphine.

The effect of secergan was studied during operative cholangiography in three patients and it was seen that it could resolve spasm of the sphincter caused by the mechanical trauma of exploration of the duct.

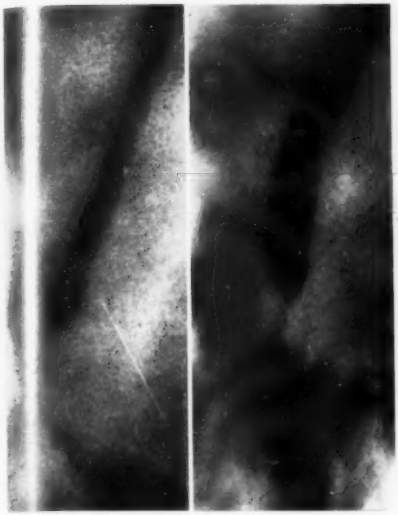

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Fig. 2. Tomograms during cholegraphy, normal findings. a) Before, and b) 20 min after secergan. Increased visibility of distal part of duct and widening of its diameter in (b).

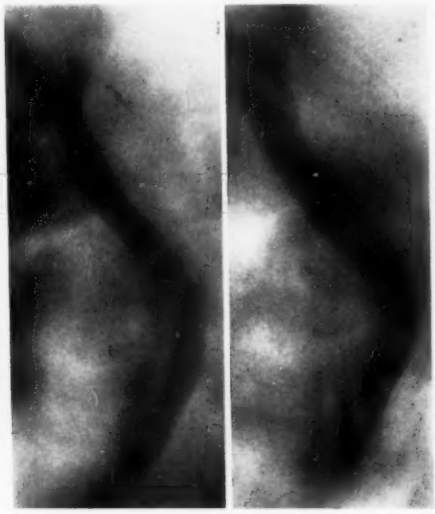

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Fig. 3. Tomograms during cholegraphy. Stone in common bile duct. a) Before, and b) 20 min after secergan. In (b) increased visibility of distal part of duct and widening of its diameter.

The drug was tried on 144 patients undergoing cholegraphy prior to cholecystectomy. The result was in agreement with the previously mentioned results, *i. e.* cessation of all contractions in the duodenum and the sphincter. When the drug had acted for 15 to 30 minutes an increase in width of the common bile duct could be seen. The degree of this dilatation of the duct varied considerably from patient to patient.

The drug improved the quality of the roentgenograms in cholegraphies in several ways:

1. It eliminated effectively the risk of blurring by duodenal peristalsis. Without the drug, blurring by this source has to be avoided by short exposure times, which if fine focus tubes are used often means a moderate value of mAs. A higher current and lower kilovoltage, which means increased contrast, are made possible by secergan.

2. The inhibition of sphincter activity resulted in improved filling of the distal portion of the duct.

3. The dilatation of the ducts resulted in the whole biliary tree being better outlined.

As the width of the duct is of diagnostic importance it is necessary to obtain cholegrams in which the diameter can be measured before the drug is given.

Side-effects. The patients sometimes experienced a dryness of the mouth, otherwise no ill-effects were observed.

SUMMARY

Secergan was tested in barium meals, cholegraphies, and operative and secondary cholangiographies, cineroentgenography being used in the last group. It was found that contractions of the duodenum and the sphincter of Oddi, which normally occur synchronously, were completely inhibited by the drug. Cholegraphy was considerably improved.

ZUSAMMENFASSUNG

Secergan wurde bei Bariummahlzeit, Cholegraphie und sowohl operativer als auch sekundärer Cholegraphie geprüft, in der letzten Gruppe bei Verwendung von Kinematographischen Aufnahmen. Es wurde gefunden, dass die normalerweise synchron ablaufenden Kontraktionen des Duodenums und Sphinkter Oddi durch das Mittel gar nicht in Erscheinung treten. Die Cholegraphie ergab dadurch bedeutend bessere Resultate.

RÉSUMÉ

L'auteur a expérimenté le secergan dans des repas barytés, des cholégraphies et des cholangiographies per-opératoires et secondaires, utilisant la cinéradiographie dans ce dernier groupe. Il a constaté que les contractions du duodénum et du sphincter d'Oddi, qui normalement sont synchrones, sont complètement inhibées par cet agent pharmacodynamique. La cholégraphie est très améliorée.

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TOMOGRAPHY OF THE MIDDLE EAR IN COLUMELLA OPERATIONS

Stapedectomy and autotransplantation of the ossicles

by

Bent Langfeldt

Tomography of the temporal bone is a method of examination so instructive that it is only natural that it has become indispensable for a demonstration of the finer details of this complex bone. Unidirectional (linear) tomography is still the most common form of examination, but the multidirectional hypocycloid technique is gaining ground.

Ziedses des Plantes (1932) and Bartelink (1933) used a 'curvilinear' technique in a few cases.

Frey (1956) used the polytome in studies of specimens of normal temporal bones, and in 1957 published a paper in which investigations on congenital anomalies of this bone performed with the polytome were reported. Tarp (1959) studied 70 cases (30 normal subjects and 40 patients) by means of the polytome, using hypocycloid movements. François & Barrois (1959) used the polytome and hypocycloid movements with various projections in the study of normal temporal bones and reported their observations with regard to the tomographic anatomy. As shown by several investigators (François, Frey, Tarp), the polytome (make Massiot, designed by Sans and Porcher) is a highly suitable tomographic unit for the examination of the finer details of the temporal bone.

We use exclusively the polytome in our tomographic studies of the temporal bone. The hypocycloid (clover-leaf) movement of the roentgen tube gives the greatest 'blurring' of points outside the tomographic plane. The distance from the focus to the fulcrum is fixed at 110 cm, and the

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Fig. 1. Columella effect of the incus. Stapes removed. Incus re-introduced into the middle ear, with its short process in the oval window niche. The tympanic membrane connected to the long process of incus; malleus intact (after HALL & RYTZNER).

Fig. 2. Columella effect of the malleus. Incus and stapes removed. Malleus re-introduced into the middle ear with its specially shaped head in the oval window niche (after HALL & RYTZNER).

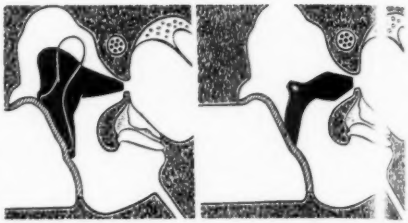

Fig. 1. Fig. 2.

magnification factor is either 1.3 or 1.6; at a tomographic angle of 4.8°, the thickness of the sections is 1.2 mm. These technical data render the polytome an ideal unit for a clear demonstration of the auditory ossicles, which is of paramount importance in many affections of the middle ear. The normal lengths of the malleus, incus and stapes are approximately 8, 6 and 3 mm, respectively.

As is well known, it is as yet impossible radiographically to render visible even severe otosclerotic changes, but the new procedures in otosclerotic surgery with stapedectomy and autotransplantation of the ossicles have intensified the interest in the radiology of these bonelets. Both in radiology and otology, the interest concentrates on the so-called 'columella operation' described in 1957 by HALL & RYTZNER. Before this operation can be performed, the otologist must have an exact knowledge of the pathologic processes in the middle ear. He must know the extent of the epitympanic recess (attic), the relation of the facial canal to surrounding structures and the state of the ossicles, i. e. whether they are congenitally absent, normally developed, deformed or destroyed. After the osteoplastic intervention, the otologist must also have information as to the exact position of the autotransplantation.

Columella operations. Birds have only one ossicle, the columella, for the transmission of sound waves. BÉKÉSY showed that the creation of such a simple connexion in man causes only a minor degree of hearing impairment.

In attempted stapes mobilization, the crura of the stapes may easily fracture. As, however, an unbroken ossicular chain is required for an optimal improvement in hearing, this chain must be re-established (HALL & RYTZNER 1958, ROSEN 1953). This requirement can be fulfilled by the columella operation. After unsuccessful mobilization of the stapes, its fractured crura are removed, and a fenestra in the footplate of the stapes is created. The incus is then extracted and at once re-implanted with its short or long process in the fenestra, while the tympanic membrane is folded back against the other process, or the body of the incus, while

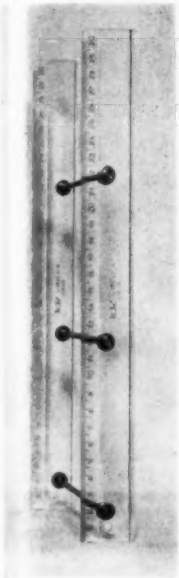

Fig. 3.

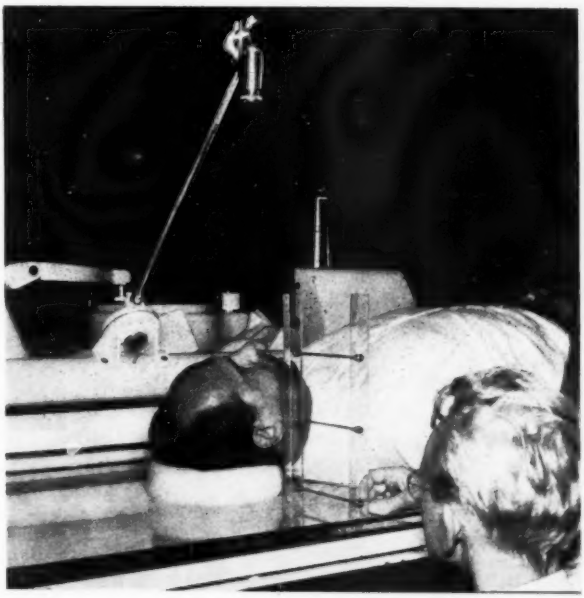

Fig. 4.

Fig. 3. Sighting device consisting of two transparent plastic rulers used in the determination of the height of the section above the table top. Parallactic errors are by means of the two scales avoided.

Fig. 4. The sighting device in use on the tomograph.

the malleus is left intact. In this way, a new bridge, a columella, is established, across which the vibrations of the tympanic membrane can be transmitted to the internal ear (Fig. 1).

In certain cases in which the incus has been destroyed, a columella may be formed by the malleus, the specially shaped head of which is then placed in the fenestra (Fig. 2).

Tomographic technique

For the demonstration of the auditory ossicles we employ two standard positions, viz. supine for anteroposterior views and lateral decubitus for lateral views. Each ear is studied separately.

In tomography in the supine position we use the magnification factor 1.3 and hypocycloid movements. Exposures are made at intervals of 2 mm, so that 12 exposures cover a thickness of 2.4 cm. The film size is 24 × 30 cm, with four exposures on each film. In addition, we use a diaphragm giving a circular area of exposure of 9 cm in diameter. The exposure factors usually employed are 90 to 105 kV, about 100 mAs and 0.3 mm focus.

In the determination of the height of the section above the table top we have found a sighting device made of transparent plastics very useful. It consists of two rulers fixed to each other at distances of 14 cm by means of brass links (Fig. 3). In this way parallactic errors are avoided. The sighting device is placed on the table top, and we aim at the posterior wall of the external auditory meatus. The height of the section above the table top is read on the rulers, following which the tomograph is adjusted to the value obtained (Fig. 4).

Fig. 5. A clear-washed roentgen film, provided with two lines crossing at right angles, placed at the upper part of the posterior wall of the external auditory meatus, ensures correct positioning. The helix is inserted through a hole in the film which is fixed to the head with adhesive tape.

In tomography in the lateral position we also use hypocycloid movements and intervals of 1 mm between the sections. Experience has shown that, in this position, the best visibility of the ossicles is obtained by using the magnification factor 1.6. A diaphragm giving a circular area of exposure, 6 cm in diameter, is employed. The film size is 13 × 18 cm, and the exposure factors are those mentioned above.

In the lateral decubitus, positioning of the patient is difficult, because it is the side nearest to the table that is to be exposed, and the table top is not transparent.

To overcome the difficulty we use a clear-washed roentgen film, in which a hole is cut and through which the external ear (helix) of the patient is inserted. The film should be sufficiently large (e. g. 24 × 30 cm) as to extend well outside the contours of the head. With a wax pencil two lines at right angles are drawn on the film, which is then so placed that the cross is at the upper part of the posterior wall of the external auditory meatus (Fig. 5). It is important that the ear is free, and that the film is fixed to the skin only in front of or behind the ear. In this way any small movements of the head are revealed by a displacement of the cross.

With this film on the ear the patient is then so placed on the table that the point where the lines intersect coincides with the light spot indicating the central ray. The height above the table top can then be determined by means of the sighting device.

Normal ossicles in two patients placed in the supine position during the exposure are shown in Fig. 6, a and b. The malleus, epitympanic recess and the spur of the attic wall are distinctly seen. In Fig. 6c and Fig. 7a

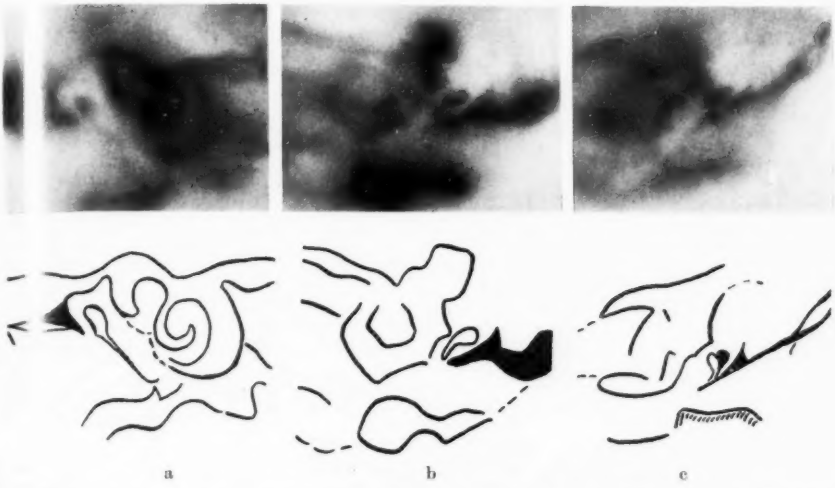

Fig. 6. a) and b) Normal ossicles in two patients, supine, right and left side, respectively, and 10.4 and 9.0 cm above the table. Head of malleus, spur of attic wall and epitympanic recess are all well defined. c) Normal left ossicles in a girl, 11 years old, 7.4 cm above the table. The thin spur is clearly visible. Malleus and body of incus (black) normal.

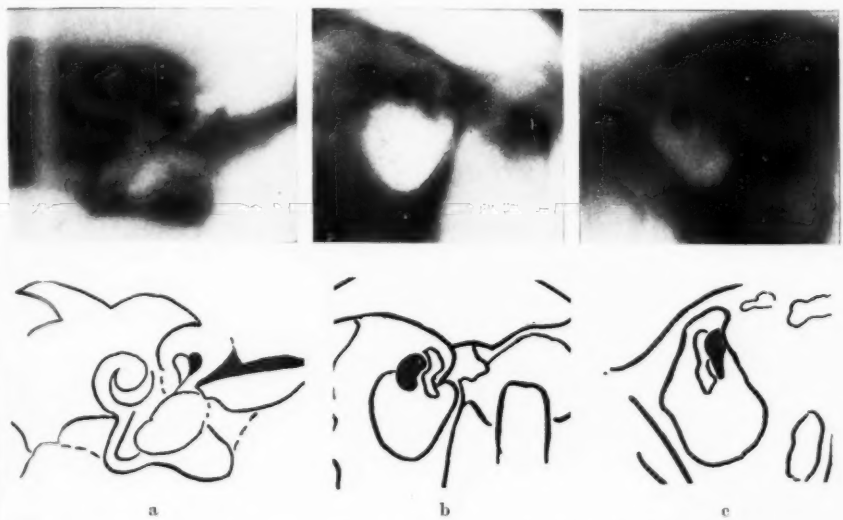

Fig. 7. Normal ossicles. a) Left side, supine, 8.2 cm above table. Normal malleus and body of incus (spur and incus black). b) Left side, lateral, 2.1 cm above table. Incus and incudo-malleal joint clearly visible. c) Right side, lateral, 9.7 cm above table. Incus and incudo-malleal joint visible.

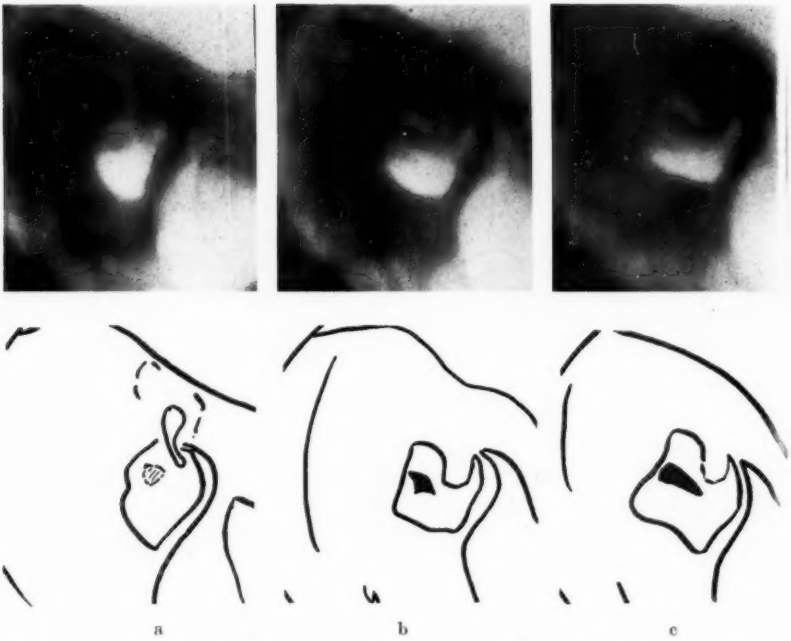

Fig. 8. Appearances after columella operation, latera position, left side. a) 2.6 cm above table. The malleus is intact. Centrally the incus is faintly visible. The normal incudo-malleal joint is not seen. b) 2.9 cm above table. The malleus is faintly, and the incus clearly visible. The latter is displaced and has been 'turned'. c) 3.0 cm above table. The incus is still clearly visible.

not only the malleus, but also part of the body of the incus are visible. In Fig. 7. b and c, normal ossicles in tomograms taken in the lateral position are shown. The incudo-malleal joint is visible.

The following tomograms illustrate the appearances after the sequelae of columella operations. It is evident that osteoplastic surgery has been performed on the ossicles. The incus has been 'turned' as previously described; it is displaced centrally and is not in contact with the malleus, which is intact. The normal incudo-malleal joint is not visible.

Conclusion

Tomography of the auditory ossicles by the polytome, and hypocycloid movements, with the patient in the supine and lateral positions, using intervals of 2 and 1 mm, respectively, between the sections, provides optimal conditions for an accurate definition of the finer details of the temporal bone.

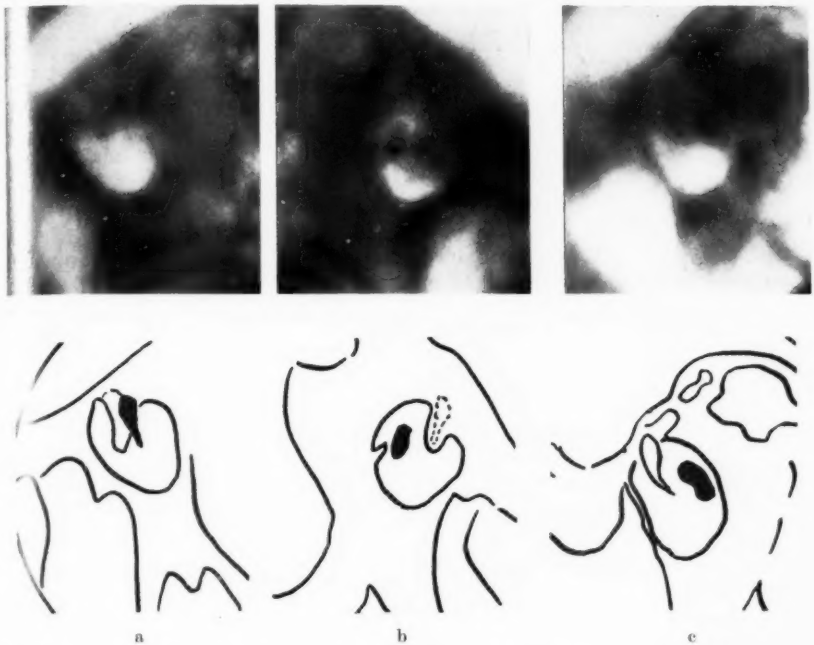

Fig. 9. Appearances after columella operation. a) Right side, lateral, 2.7 cm above table. Incus is seen, normal conditions. b) Same patient as in (a), left side, 2.9 cm above table. The malleus is in its proper place, while the incus is displaced centrally and posteriorly. c) Lateral, 6.1 cm above table. The malleus is in its proper place, while the incus is displaced centrally and posteriorly.

The information thus obtained is a prerequisite for the autotransplantation of the ossicles, the so-called columella operation, in which the otologist after extraction of the crura of the stapes, and the establishment of a fenestra in the footplate, turns the incus and re-implants it in the middle ear as the only sound-transmitting element, or forms a new transmission mechanism of the malleus alone.

The tomographic technique described gives information, pre-operatively of the state of the ossicles and their applicability in the autotransplantation and, postoperatively, of the exact position of the autotransplant.

SUMMARY

A technique of tomography of the auditory ossicles is described. Tomograms showing normal ossicles and the appearances after the 'columella' operation (stapedectomy and autotransplantation of the ossicles) are presented.

ZUSAMMENFASSUNG

Es wird ein technischer Verfahren der Tomographie der Gehöhrknöchelchen beschrieben. Die Tomogramme der normalen Ossiceln und ihr Aussehen nach der 'columella'-Operation (Stapedektomie und Autotransplantation der Ossiceln) werden gezeigt.

RÉSUMÉ

L'auteur décrit une technique de tomographie des osselets de l'oreille moyenne. Il présente des tomographies montrant des osselets normaux et l'aspect après l'opération de la columelle (stapédectomie et autotransplantation des osselets).

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CIVIL STATUS DISTRIBUTION IN 1822 CASES OF CARCINOMA OF THE UTERINE CERVIX

by

O. G. A. Berggren

In 1957 the writer published a study entitled: 'Demographic studies on carcinoma of the uterine cervix in Sweden.' In Chapter II, treating the possible causes of carcinoma of the uterine cervix, in the section on civil status, we read on page 20: 'Numerous writers have observed a lower incidence of cervical cancer in unmarried than married women, widows and divorcées. It is emphasized that the cervical cancer risk is greater at every age among married women and widows than among unmarried women (STOCKS). Between ages 45 and 65 years the incidence is about seven times as great among married women and widows as among unmarried women. MALIPHANT writes that a woman who has reached 35 years of age has twice the chance of developing cervical cancer if she is married.'

Similar results were reported by DORN, LOMBARD & POTTER, and GILLIAM, inter alios. An unexplained relation between the divorced state and the incidence of cervical cancer has also been discovered. In a series of cervical cancer patients 20.7 per cent were divorced, while in a control material the percentage of divorced women was 5.7 (CORSCADEN 1951).

The study was based on a material of 1 822 cases of carcinoma of the uterine cervix in Sweden, from the years 1935, 1940, 1945 and 1950, which represents the material from four hospitals in Sweden, to which

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practically all cases from the entire country are referred for irradiation therapy. Some of the patients were referred for irradiation therapy after operation. The material, in addition, includes patients who were put on record, but not treated for some reason, *e. g.* because too old or because refusing treatment. Because, however, of the particular recording system practized practically all cases of carcinoma of the uterine cervix, diagnosed during these years, could be included in the material. (For further details, see Acta Radiologica, Supplementum 145, p. 35.)

The material in question was considered in relation to the whole Swedish female population in the years 1935, 1940, 1945 and 1950, and divided into age groups, classified on the basis of residence in rural districts or towns, according to county of residence, or residence in the capital, and according to civil status. The material has not previously been analyzed with respect to the latter basis of classification.

Since the material is so extensive and includes an entire country, and since we have earlier reports that divorcées run a greater risk of contracting carcinoma of the uterine cervix than married women and widows, and that these in turn are affected to a greater extent than unmarried women, this material of 1 822 cases, which can be correlated with the female population of an entire country and the civil status distribution in that population, has been analyzed in this respect.

In order to make the different groups comparable with regard to the civil status distribution, the age groups from 0 to 20 years have been eliminated from the tables presented, and all cases of cervical cancer have been correlated with the figures thus obtained for single, married, widowed and divorced women. It should be noted that among the 1 822 patients were none under 20 years of age. Thus, tables have been assembled, presenting the cervical cancer incidence in single women for the year 1935, and the calculated number of cases of cervical cancer in married, widowed and divorced women, computed with the morbidity for single women for the year 1935, according to residence in towns or rural districts, and for the entire country's female population, over 20 years of age, for the same year. The figures thus obtained for each age group have been added, giving a calculated number of cases computed on the basis of the morbidity for single women. In the same way, tables have been compiled for the years 1940, 1945 and 1950, comprising in all 12 tables which are available by applying to the author.

The figures thus computed have been compared with the actual numbers of cases in the married, widowed and divorced women groups for, respectively, all towns, all rural districts and the entire country. This gave the proportional cervical cancer morbidity in the respective civil status groups shown in the tables combined for the four years. The figures thus obtained are now presented in Table 1 and Diagram 1. These show

Table 1

Combination of final results from author's tables 1 to 12 (See text p. 138).

	Single	Married	Widowed	Divorced
19[illegible]:				
All [illegible]owns	1	3.25	2.33	4.18
All [illegible]ural districts	1	1.72	1.22	4.23
En[illegible]e country	1	2.32	1.71	4.75
19[illegible]:				
All [illegible]owns	1	2.37	1.13	4.26
All [illegible]ural districts	1	2.39	2.21	4.29
En[illegible]e country	1	1.96	1.28	4.67
194[illegible]:				
All [illegible]owns	1	2.26	2.25	3.37
All [illegible]ural districts	1	1.58	2.32	4.42
Entire country	1	1.88	2.17	4.03
1950:				
All towns	1	1.72	3.26	3.52
All rural districts	1	1.48	1.04	3.30
Entire country	1	1.58	2.18	3.71

Comment: The fact that the figures for the entire country do not always lie between the figures for all towns and all rural districts for the respective years is quite natural and is due both to the difference in morbidity in towns and rural districts for the respective years and to the varying proportions of the age groups in the different age classes of the respective civil status groups.

a rather uniform picture throughout, for the relation between different civil status groups with carcinoma of the uterine cervix.

The difference in morbidity for single, married, widowed and divorced women is most striking in rural districts. The difference is less pronounced for the towns, but in both environments marked differences are apparent. The figures for the entire country show the incidence in married women and widows to be approximately half that in divorced women, and half as high in single women as in married and widowed. This difference is similar for the years 1935 and 1940. The morbidity figures for widows in the materials from both these years are lower for towns, rural districts and the entire country than those for married women. In 1945 the incidence in widows rose to the level of that in married women in towns, while it exceeded that in married women in both rural districts and in the country as a whole. For that year also, however, the incidence in divorced women

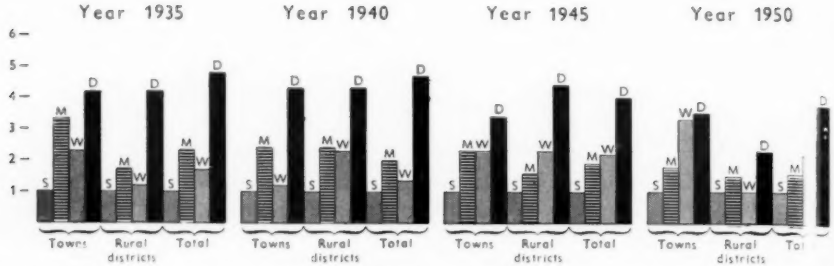

Diagram 1. Incidence of cervical cancer in the different civil status groups. S — single, M — married, W — widowed, D — divorcées.

was higher than in other civil status groups. In 1950 the incidence in widows rose above that in married women in the towns. It was also higher for the entire country but not for the rural districts. The incidence in divorcées still dominated that year.

In Table 2 and Diagram 2 the percentual distribution among the different civil status groups, for 1935, 1940, 1945 and 1950 are given.

Table 2

Percentual distribution in Sweden according to civil status of the female population over 20 years of age in the towns, in the rural districts and in the country as a whole. (See text pp. 140—141.)

	Single %	Married %	Widowed %	Divorced %
1935:				
All towns	39.10	48.90	9.96	2.04
All rural districts	30.47	57.25	11.67	0.61
Entire country	33.87	53.96	10.99	1.17
1940:				
All towns	34.41	53.26	9.91	2.42
All rural districts	27.47	60.24	11.55	0.74
Entire country	30.40	57.30	10.86	1.45
1945:				
All towns	28.88	58.50	9.75	2.87
All rural districts	23.87	63.89	11.37	0.87
Entire country	26.19	61.40	10.62	1.79
1950:				
All towns	24.58	61.89	10.03	3.50
All rural districts	21.15	66.54	11.22	1.10
Entire country	22.89	64.17	10.61	2.33

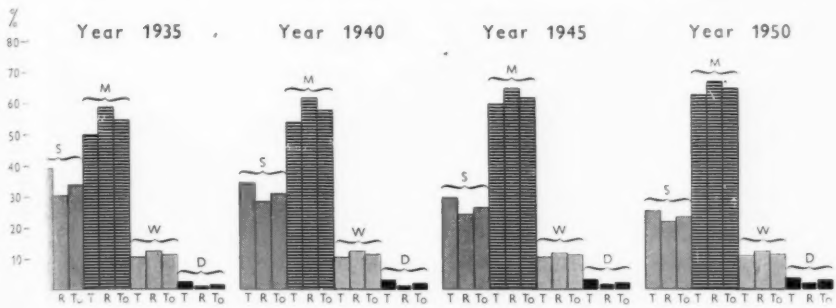

Diagram 2. Percentual distribution of the female population in Sweden, over 20 years of age, in towns (T), rural districts (R), and the entire country (To), classified according to civil status: S — single, M — married, W — widowed and D — divorcées.

Among other changes evident from these is the decrease in the group of single women in the entire country from 33.87 per cent in 1935 to 22.89 per cent in 1950. The married group has increased for the entire country from 53.96 per cent in 1935 to 64.17 per cent in 1950. The tendency is more pronounced in the towns than in the rural districts. The percentage of widows has remained comparatively unchanged through the years, while the divorcées have increased slightly from 1.17 to 2.32 per cent. The tendency is more marked in the towns than in the rural districts.

The results presented in the work now discussed (Supplementum 145 to Acta Radiologica) may be summarized as follows:

1. The risk that carcinoma of the uterine cervix will develop is very much greater for women residing in towns than for those in rural districts in Sweden.

2. 'Classified milder' forms of carcinoma of the uterine cervix comprise, in the material studied, a larger proportion of the cases in each successive reported year. This applies to the series from all the four clinics.

3. The investigation shows that the rural districts present percentually more of the 'classified more severe' forms of carcinoma of the uterine cervix than do the towns.

4. The morbidity maxima in carcinoma of the uterine cervix have shifted towards younger age groups during the period covered by the investigation. This is particularly true of the rural district population.

5. The demonstrated increase of carcinoma of the uterine cervix during recent years may be partially but not entirely explained by the drop in the percentage of the female population living in rural districts, *i. e.* 'the flight from the land'. With the higher morbidity in the towns this must mean that the disease is occurring in an increasing number of women.

6. The investigation shows that the increase in the incidence of carcinoma of the uterine cervix in the country as a whole may be attributed to the rural district population.

7. Norrland, the northernmost of the three main sections of Sweden, presents a larger proportion of the 'classified more severe' forms of carcinoma of the uterine cervix than does the rest of the country.

To these observations we can now add the following concerning the civil status question:

8. The relation between the different civil status groups, with respect to cervical cancer incidence, is 1:2:1.5:4.5 for, respectively, single, married, widowed and divorced groups for the years 1935 and 1940. This means that married women and widows had about double the cervical cancer incidence of single women and that divorced women had about four times as much chance of contracting carcinoma of the cervix during those years. This difference was less pronounced in 1945 and 1950 but still showed the same tendency.

9. There has been a change in the percentual distribution according to civil status during the interval covered by the investigation. This applies mainly to the relation between single and married states. In 1935 about 34 per cent of the female population over 20 years of age in the entire country were single and about 54 per cent were married. The figures have since changed successively in 1940, 1945 and 1950 to become 23 per cent single and 64 per cent married.

10. Accordingly, there has in more recent years been a percentual increase in the number of married women, and a percentual decrease in the number of single women. The percentage of widows, on the other hand, has remained comparatively constant during the reported years, and the divorcées have increased percentually from 1.17 per cent in 1935 to 2.32 per cent in 1950. With respect to the civil status distribution between towns and rural districts, single and divorced women have percentually greater representation in the towns, with the reverse being true of the married and widowed women.

1. Since the married women are the largest and most dominant group in the female population — in recent years about 64 per cent —, and this group has increased by more than 10 per cent, while the single group has decreased to about the same extent and the widowed group has remained relatively unchanged during the years, and the divorcées represent only from 1 to 3 per cent, the shift in the female population with respect to the civil status distribution has taken place mainly between single and married groups. The double incidence of cervical cancer among married women, as compared with the incidence in single, partly explains why the incidence of carcinoma of the uterine cervix has risen during recent years.

2. The group of divorcées represents only a very small percentage of the material, but the group has doubled in size percentually, and its cervical cancer morbidity is four times that of the single group, wherefore there has been an increasing number in this group as well.

In a material comprising 1822 cases of carcinoma of the uterine cervix, classified according to civil status, among other factors, it has been found that married women and widows contract the disease approximately twice as often as unmarried women, while the risk is approximately four times as great for the divorcées as for the single women.

Throughout, the rural districts show percentually lower figures for married and widowed women in comparison with the figures for single women than do the towns. For the divorcées there is no great difference between rural districts and towns.

Discussion

A number of investigators have contended that sexual activity is significant. In support of this view we have, for example, Röjel's investigations from Copenhagen (See references in the author's main study), showing that the incidence in prostitutes is four times that in a control material of the same age, and similar in other respects. If we pursue further this line of thought it seems to incidate that the divorcées would have a greater sexual activity than the married women, for example. This would scarcely seem likely, in the sense of more frequent coitus, but it might be possible that divorced women have a greater number of sexual partners than have single women, or married women and widows.

The fact that the incidence in widows was lower than in married women, during the years 1935 and 1940, while the opposite is true during the years 1945 and 1950, might be interpreted as a tendency towards a change in the sexual behaviour pattern of the widow during the last two years recorded. It may be observed that the incidence in widows then

closely approaches that in the divorcées. The Second World War may have brought about a change in the sexual norms for widows. As to the divorcée group, it may be that sexual maladjustments in certain marriages, indicating an increased sexual need, may possibly lead to serious dissension and result in divorce.

The increased percentage of married women and the decreased percentage of single women, which means a shift between these groups of more than 10 % from 1935 to 1950, are rather remarkable, and they further contribute to the explanation of the rise in the incidence of carcinoma in the uterine cervix in Sweden.

It is not inconceivable that there may be a factor of infectious irritation in the etiology of the disease.

SUMMARY

A material of 1 822 cases of carcinoma of the uterine cervix has been correlated with the entire female population, over 20 years of age, in Sweden in 1935, 1940, 1945 and 1950, with respect to certain known data in the structure of the population. The relative incidence in 1935 and 1940 in single, married, widowed and divorced women was approximately 1:2:1.5:4.5. The difference is less marked for 1945 and 1950 than for 1935 and 1940, but the tendency is nevertheless distinct and definite through all the recorded years. The corresponding figures for 1945 and 1950 are approximately 1:1.5:2:4. The group of divorced women represents only a small percentage of the material, but the percentual magnitude of the group has doubled and its cervical morbidity is about four times as high as in the single group. A factor of infectious irritation is conceivable in the etiology of the disease.

ZUSAMMENFASSUNG

Ein Material von 1 822 Fällen von Carcinoma cervix uteri wurde mit der gesamten weiblichen Bevölkerung im Alter über 20 Jahren in Schweden während der Jahre 1935, 1940, 1945 und 1950 verglichen und zu bestimmten Daten dieser Bevölkerung in Relation gesetzt. Die relative Cancerhäufigkeit während 1935 und 1940 für einzelstehende, verheiratete, verwitwete und geschiedene Frauen war annähernd 1:2:1.5:4.5. Der Unterschied für 1945 und 1950 ist weniger ausgesprochen als für 1935 und 1940, die Tendenz während all der registrierten Jahre ist jedoch deutlich und klar. Die korrespondierenden Zahlen für 1945 und 1950 sind annähernd 1:1.5:2:4. Die Gruppe der geschiedenen Frauen repräsentiert zwar nur einen kleinen Anteil des Materials, die prozentuelle Grösse dieser Gruppe hat sich jedoch verdoppelt und ihre cervicale Morbidität im Vergleich zur Gruppe der einzelstehenden Frauen vervierfacht. Ein Faktor von infektiöser Reizung in der Äthiologie dieser Erkrankung ist denkbar.

RÉSUMÉ

L'auteur a étudié un matériel de 1 822 cas de cancer du col de l'utérus corrélativement à la population féminine totale, agées de plus de 20 ans, en Suède, en 1935, 1940, 1945 et 1950, en tenant compte de certaines données connues concernant la structure de la popula-

tio . La fréquence relative en 1935 et 1940 chez les célibataires, les femmes mariées, ve ves et divorcées était approximativement de 1:2:1.5:4.5. La différence est moins pr noncée en 1945 et 1950 qu'en 1935 et 1940, mais la tendance est cependant indiscutable et ette sur toutes les années étudiées. Les nombres correspondants pour 1945 et 1950 sor approximativement 1:1.5:2:4. Le groupe des femmes divorcées ne représente qu'un pet t pourcentage de ce matériel, mais le pourcentage de ce groupe a doublé et l'atteinte du ol utérin y est environ quatre fois plus fréquente que dans le groupe des célibataires. On peut penser qu'un facteur d'irritation infectieuse intervient dans l'étiologie de cette aff tion.

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RADIOPROTECTIVE EFFICACY OF SODIUM CYANIDE

by

P. De, A. Bose and *S. Bose*

The question of the radioprotective efficacy of sodium cyanide is far from settled. DOWDY et coll. (1950) observed no radioprotective effect of sodium cyanide in rats (3 mg/kg bodyweight) with 800 r up to the 11th day after irradiation, taking the survival index of the rat as the biologic criterion. BACQ et coll. (1951) observed the radioprotective efficacy of sodium cyanide (0.1 mg) in mice up to 31 days after 700 r irradiation at a level of 50 to 80 per cent, with the survival index as the biologic reference. The radioprotective efficacy of sodium cyanide was also observed (BACQ et coll. 1955), with the growth rate of *Pisum sativum* root as the reference system.

The present investigation was undertaken in order to make a quantitative assessment of the radioprotective efficacy of sodium cyanide, with the mitotic index of rat bone marrow cells as the biologic reference system.

Material and Method

The experiments were conducted on inbred adult Indian albino rats of the same strain, of both sexes, and with the same average bodyweight, about 125 g. Each experiment was performed with three series of

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an nals, consisting of normal controls, irradiated controls given a whole bo y dose of 800 r with 250 kV roentgen radiation (1.5 mm Cu HVL), an two protected groups to which a whole body dose of 800 r, from the sa e quality of radiation, was administered immediately after the in peritoneal administration of sodium cyanide, in doses of 1.5 mg/kg an 3 mg/kg bodyweight respectively. All rats were given an *ad libitum* di (wheat 66 %, sweet oil 1 %, Bengal gram (pulse) 15 %, shark liver oil %, fishmeal 7 %, ground nuts 5 %, yeast powder 5 %, and water). Al rradiations were administered in a specially designed plastic chamber, wl re fairly accurate dose measurements were possible and the irradiatic conditions were reproducible. Animals under normal control series re ived no irradiation.

The total number of animals involved in these experiments were 110, of hich 30 rats were kept as normal controls and 30 rats as irradiated co trols. Of the protected series (50 rats), 19 were injected with 1.5 mg/kg so um cyanide and 31 were injected with 3 mg/kg sodium cyanide im ediately before irradiation.

On the first day, i. e. 24 hours after irradiation (800 r), 24 rats were ex mined and bone marrow tissues collected; of these, 6 were of the normal co trol series, 6 of the irradiated control series, 6 protected with 1.5 mg/kg sodium cyanide, and 6 protected with 3 mg/kg sodium cyanide. On the third day, 16 rats were investigated and bone marrow tissue collected from 4 of the normal controls, and from 4 of the irradiated controls, and 4 were given 1.5 mg/kg sodium cyanide and 4 given 3 mg/kg sodium cyanide. On the 6th day after irradiation, 54 rats were examined, of which 16 were of the normal control series, 16 of the irradiated control series, and 5 of the 1.5 mg/kg, and 17 of the 3 mg/kg bodyweight sodium cyanide protected series.

On the 9th day after irradiation, 16 rats were examined of which 4 were of the irradiated normal control series, 4 of the control series and 4 of the 1.5 mg/kg and 4 of the 3 mg/kg bodyweight sodium cyanide protected series.

Bone marrow was collected from the right femur under the intraperitoneal anaesthesia of Nembutal, on the 1st, 3rd, 6th and 9th days after irradiation, and immediately fixed in Susa for 18 hours. It was then dehydrated and blocked, and serial sections of 5 μ thickness were prepared from each rat. The ordinary hematoxylin (Ehrlich's) and eosin staining procedure was followed.

The scoring of the data was performed under $\times$ 1 250 magnification, in a random pattern, with a square grid in the ocular of the microscope limiting the field of view; about 2 000 nucleated cells were counted, with a differential count of mitotic cells and non-mitotic nucleated cells in each field. The mitotic index was expressed as a percentage, as in the following formula:

$$\frac{\text{Mitotic cells} \times 100}{\text{Total nucleated cells}}$$

For each animal there was one mitotic index comprising about 2 00 nucleated, randomly counted bone marrow cells.

Results

With 1.5 mg/kg bodyweight sodium cyanide the mitotic indices of bone marrow cells, on the first day after irradiation, were 1.33 ± 0.063, 0.21 ± 0.077, and 0.51 ± 0.084 in the normal control, irradiated control, and protected series, respectively. On the third day after irradiation the mitotic indices were 1.37 ± 0.084, 0.27 ± 0.084, and 0.63 ± 0.089 in the normal control, irradiated control, and protected series, respectively. On the sixth day after irradiation, the mitotic indices were 1.32 ± 0.089, 0.30 ± 0.084, and 0.82 ± 0.095 in the normal control, irradiated control and protected series, respectively. On the ninth day following irradiation the mitotic indices were 1.33 ± 0.084, 0.37 ± 0.077, and 0.82 ± 0.071 in the normal control, irradiated control and protected series, respectively (Table 1 and Diagram 1).

With 3 mg/kg sodium cyanide the mitotic indices of the bone marrow cells on the first day after irradiation were 1.33 ± 0.063, 0.21 ± 0.077, and 0.60 ± 0.071 in the normal control, irradiated control and protected series, respectively. On the third day after irradiation, the mitotic indices were 1.37 ± 0.084, 0.27 ± 0.084, and 0.68 ± 0.032 in the normal control, irradiated control, and protected series, respectively. On the sixth day of irradiation, the mitotic indices were 1.35 ± 0.089, 0.29 ± 0.084, 0.80 ± 0.077 in the normal control, irradiated control, and protected series, respectively. On the ninth day of above irradiation, the mitotic indices were 1.33 ± 0.084, 0.37 ± 0.077, and 0.85 ± 0.071 in the normal control, irradiated control, and protected series, respectively (Table 2 and Diagram 2).

Discussion

In determining the radioprotective efficacy of sodium cyanide the mitotic index of bone marrow cells has been utilised as the biologic reference system. Bone marrow cells were selected by reason of their constant supply of physiologically active cells (MAXIMOW et coll. 1952), their increased incidence of mitosis (THORELL 1947) and their highly radiosensitive behaviour (BLOOM 1948).

GOLDFEDER (1951) in her radiobiologic research utilised the mitotic index as the reference for the quantitative estimation of growth rates of tumours, before and after irradiation.

Table 1

Correlation of the radioprotective efficacy of 1.5 mg/kg sodium cyanide with the mitotic index of rat bone marrow cells irradiated with 800 r

	Mitotic index					't' test between n_1 and n_2	
	Normal controls (n)	Irradiated controls with 800 r (n_1)	Protected (n_2)	Percentage of mitotic damage	Percentage of mitotic protection	Value of 't'	Significant at 't'
1st day	1.33 ± 0.063	0.21 ± 0.077	0.51 ± 0.084	84	26	12	5 % and 1 % level
3rd day	1.37 ± 0.084	0.27 ± 0.084	0.63 ± 0.089	80	32	12	5 % and 1 % level
6th day	1.32 ± 0.089	0.30 ± 0.084	0.82 ± 0.095	77	50	16	5 % and 1 % level
9th day	1.33 ± 0.084	0.37 ± 0.077	0.82 ± 0.071	72	46	18	5 % and 1 % level

Table 2

Correlation of radioprotective efficacy of 3 mg/kg sodium cyanide with the mitotic index of rat bone marrow cells irradiated with 800 r

	Mitotic index					't' test between n_1 and n_2	
	Normal controls (n)	Irradiated controls with 800 r (n_1)	Protected (n_2)	Percentage of mitotic damage	Percentage of mitotic protection	Value of 't'	Significant at 't'
1st day	1.33 ± 0.063	0.21 ± 0.077	0.60 ± 0.071	84	34	14	5 % and 1 % level
3rd day	1.37 ± 0.084	0.27 ± 0.084	0.68 ± 0.032	80	37	17	5 % and 1 % level
6th day	1.35 ± 0.089	0.29 ± 0.084	0.80 ± 0.077	79	48	22	5 % and 1 % level
9th day	1.33 ± 0.084	0.37 ± 0.077	0.85 ± 0.071	72	50	17	5 % and 1 % level

In the present investigation it was found that the mitotic inhibition of bone marrow cells due to 800 r of ionising radiation were 84 %, 80 %, 77 to 79 %, and 72 % on the 1st, 3rd, 6th and 9th day after irradiation, respectively. During the period of observation, the maximum mitotic inhibitory effect (84 %) occurred on the first day of irradiation. The inhibitory effect then slowly fell to 72 % on the 9th day (Tables 1 and 2).

The radioprotective efficacies produced by 1.5 mg/kg sodium cyanide, on rat bone marrow cells irradiated with 800 r, were 26 %, 32 %, 50 %

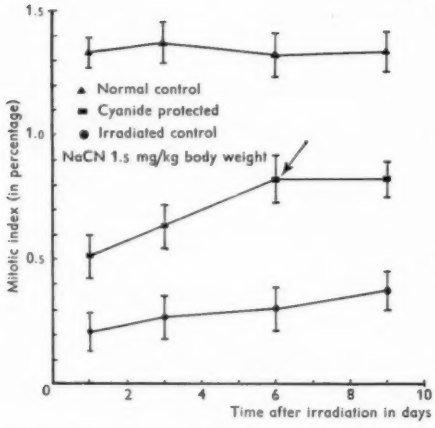

Diagram 1.

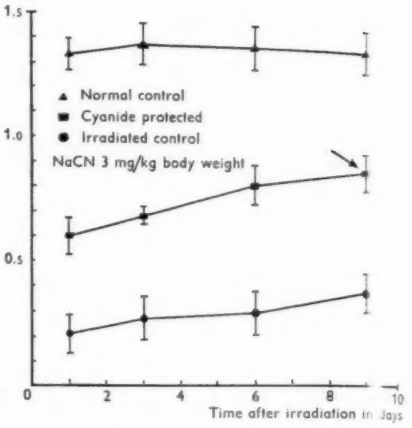

Diagram 2.

Diagrams 1 and 2. Assessment of the radioprotective efficacy of 1.5 mg and 3 mg doses, respectively, of sodium cyanide per kg bodyweight, on the 1st, 3rd, 6th and 9th days after irradiation with 800 r, with the mitotic index (with standard deviation) as reference. The maximum protection (50 %) was reached with the 1.5 mg dose (Diagram 1) on the 6th day, and with the 3 mg dose (Diagram 2) on the 9th day after irradiation (arrows).

and 46 %, on the 1st, 3rd, 6th and 9th day of irradiation, respectively. During the period, the efficacy of protection was minimum (26 %) on the 1st day of irradiation (Table 1). The maximum protective efficacy was 50 % and was reached on the 6th day of irradiation (Table 1 and Diagram 1). On the 9th day of irradiation, the efficacy of protection came down to 46 % (Table 1).

With a 3 mg/kg dose of sodium cyanide, the efficacies of protection were 34 %, 37 %, 48 %, and 50 %, on the 1st, 3rd, 6th and 9th days of irradiation, respectively (Table 2). The minimum protection was, like that of the previous dose, on the first day of irradiation. But the efficacy of protection (34 %) was better than that (26 %) produced by the previous dose on this day. The maximum efficacy of protection as in the case of the previous dose was 50 % but, on the other hand, the period of maximum efficacy was reached on the 9th day of irradiation (Table 2 and Diagram 2).

For assessing the statistical significance of the present results, a 't' test was performed for determining the nature of the difference between the mitotic indices of the irradiated control series (n_1) and the protected series (n_2) which were observed to be significant at 5 % and 1 % levels (Tables 1 and 2).

Dowdy et coll. (1950) observed no radioprotective effect to be produced by 3 mg/kg sodium cyanide after 800 r up to the 11th day, following irradiation, taking the survival index of the rat as the biological criterion. Bacq et coll. (1951) observed that in mice the radioprotective efficacy of 0.1 mg sodium cyanide per animal was 50 to 80 % up to 31 days after 700 r irradiation, with the survival index as the biologic reference. The present data, with both doses of sodium cyanide, show a maximum protection up to 50 % in the period from 6 to 9 days after 800 r irradiation (Tables 1 and 2 and Diagrams 1 and 2).

Acknowledgements

We wish to express our gratitude to Professor S. Mitra for his support and never-failing interest in this investigation. We also thank T. Mukherjee and R. Chatterjee for their kind suggestions and active co-operation, R. Ghosh for the statistical checking of the data, and S. Bhattacharya who supplied the animals.

SUMMARY

The radioprotective efficacy of 1.5 mg/kg and 3 mg/kg bodyweight doses of sodium cyanide was tested on rat bone marrow cells in vivo, irradiated with 800 r with the mitotic index as the biologic reference. With both doses the maximum protective efficacy was up to 50 % in the period from the 6th to the 9th day.

ZUSAMMENFASSUNG

Die Strahlenschutzwirkung von Natriumcyanid in Dosen von 1.5 mg und 3 mg per Kg Körpergewicht wurde in vivo an Knochenmarkzellen von Ratten nach Röntgenbestrahlung mit 800 r mittels des mitotischen Index' getestet. Mit beiden Dosierungen erreichte die maximale Schutzwirkung 50 % zwischen dem 6. bis 9. Tag der Bestrahlung.

RÉSUMÉ

Les auteurs ont testé in vivo l'effet radioprotecteur de doses de 1.5 mg/kg et 3 mg/kg de poids corporel de cyanure de sodium sur les cellules de la moëlle osseuse de rats irradiés par 800 r. Ils ont pris l'index mitotique comme critère de référence biologique. Avec ces deux doses, l'efficacité protectrice maximale a atteint 50 % du 6ème au 9ème jour après l'irradiation.

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PHYSICAL ASPECTS OF ROENTGEN THERAPY USING WEDGE FILTERS

IV. A new wedge principle using graphite and tin

by

M. Cohen

In the previous parts of this paper (COHEN 1959, COHEN and BURNS 1959) the importance of reducing the maximum skin dose has been stressed. In part I the maximum dose for an individual wedge was assigned a limit of 170 % of the central axis surface dose, in order that the 'hot-spot factor' (i. e. maximum skin dose/mean tumour dose) should not exceed 1.3 to 1.4 in a useful number of 2 or 3-field arrays. Any means of decreasing the maximum dose for the individual wedge, whilst preserving the other general features of the dose distribution (wedge slope, etc), will reduce the hot-spot factor in arrangements already within the usable range and will bring into this range other arrays at present outside it. One method of so decreasing the maximum dose, suggested in part II, is to design the wedge so that the isodose lines are curved rather than straight. Another method will be described in the present paper.

In a wedge filter of copper or similar material the essential function of the metal is to attenuate the primary radiation on one side of the beam relative to the other. Incidentally to this main function the copper also hardens the more attenuated side of the beam relative to the less at-

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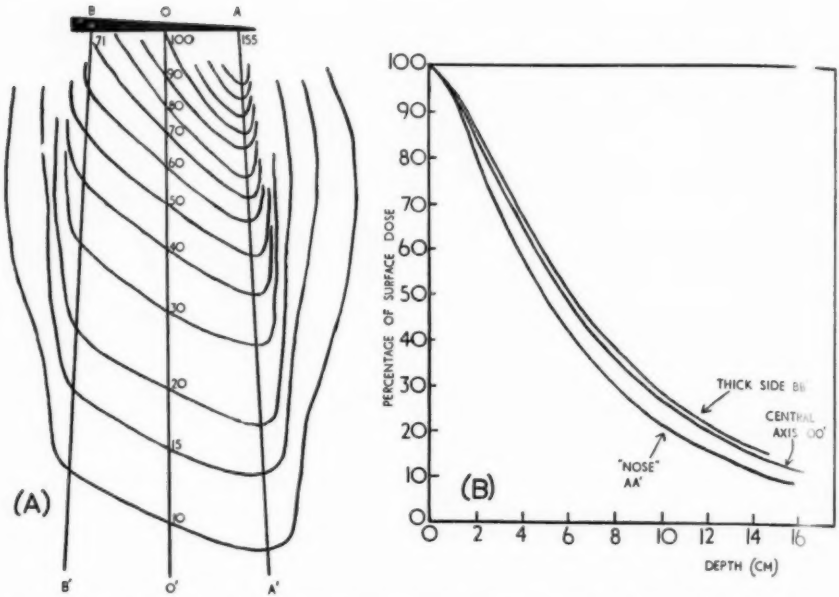

Fig. 1. A — Isodose chart of 6 × 8 cm copper wedge (HVL 1.74 mm Cu) showing lines along which depth doses have been considered. B — Depth dose curves, normalized to the surface in each case, along the three lines indicated in (A).

tenuated side. This hardening, however, plays no useful role in the action of the wedge: on the contrary, as will be shown, the effect opposes the wedging action of the filter. That this change in quality is of importance in practice as well as in theory may be shown by drawing three lines, radiating from the focus, on a wedge isodose chart (Fig. 1-A) and plotting percentage depth doses along each line, normalizing the dose at the surface to 100 % for each line. The resulting curves are shown in Fig. 1-B, from which it is clear that the main change in quality occurs between the thin side of the wedge (the 'nose') and the central axis.

The fact that the greatest percentage depth-doses occur on the thick side of the wedge means that the depth in the phantom of a given isodose line is increased on this side, i. e. its slope tends to decrease. Hence in order to achieve a given isodose slope the wedge itself has to be made thicker than would have been necessary in the absence of the hardening effect. The increased thickness of copper, in turn, leads to a higher maximum percentage surface dose, since (neglecting the effect of back-scattered radiation) this depends on the ratio of the primary beam intensity at the thin edge of the wedge to that at the central axis.

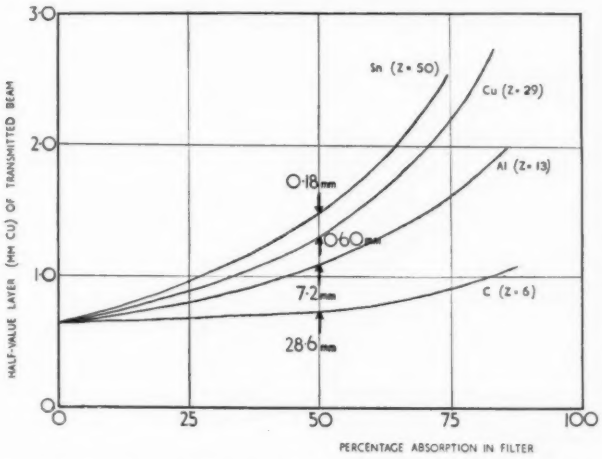

Diagram 1. Measured relationship between the quality of the beam transmitted through filters of carbon, aluminium, copper and tin, and the percentage of the incident beam absorbed in the filter.

The above arguments may be summed up in the statement that a copper wedge is comparatively inefficient. To increase the efficiency it is necessary to ensure that the maximum beam hardness occurs on the thin side of the wedge, but this cannot be achieved with a single material. A combination of two materials will, however, yield the desired result: ideally one material, for the thick side of the wedge, should attenuate without hardening, whilst the other material, for the thin side, should harden without attenuation. Such ideal materials do not, of course, exist, but an approximation to the ideal may be obtained by choosing a material of low atomic number for the thick side and one of high atomic number for the thin side. The advantage of using a high atomic number material for maximum efficiency of beam hardening was originally pointed out by THORAEUS (1932, 1934).

Efficiency of beam hardening

The quantitative aspect of beam hardening in relation to attenuation has been studied in four materials of different atomic number: carbon ($Z = 6$), aluminium ($Z = 13$), copper ($Z = 29$) and tin ($Z = 50$). The basic radiation conditions were: Watson XT1 set, 250 kV, filter 1 mm Al only, HVL 0.6 mm Cu. Absorption curves of this radiation were first measured in each of the four materials. A layer of one of the materials

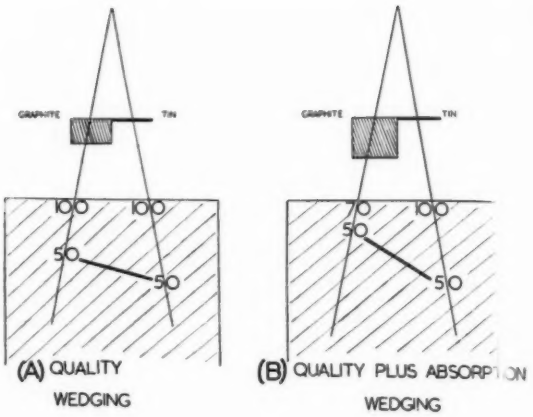

Fig. 2.

A — Sloping isodose curve produced by quality effect only, without a variation in surface dose.

B — Isodose curve of increased slope obtained by introducing an additional attenuation (and, hence, a surface variation) on the graphite side.

was then added to the aluminium filtration of the beam and an absorption curve in copper measured, from which the half-value-layer in copper of the beam with the stated filtration was deduced. Care was taken throughout to use good geometry, i. e. to reduce to a minimum the scattered radiation reaching the chamber. By repeating this procedure with other filtering layers the relationship between beam hardness, expressed as the HVL in copper, and filtration of the chosen material was obtained. Since, however, the numerical values of the thicknesses involved were quite different for the four substances, it is difficult to get a valid comparison between them if 'filter thickness' is plotted as abscissa. Instead, this scale is taken as the percentage absorption of the initial beam in the filter, i. e. in effect, beam hardness is plotted against beam attenuation. The resulting curves are shown in Diagram 1, from which it is clear that the radiation which emerges from a graphite filter after, say, 50 % attenuation, has been hardened very little (HVL 0.74 mm Cu) whereas the same attenuation in tin results in a beam of half-value-layer 1.50 mm Cu. The actual thicknesses involved, are, however, of a different order, as indicated in the diagram.

Graphite/tin wedges

The measurements shown in Diagram 1 lead one to expect that a composite wedge of graphite and tin will approximate to the 'ideal'.

Consider a block of graphite (of density 1.65 g/c.c.) and a sheet of tin placed side by side in a roentgen beam of HVL 0.6 mm Cu (Fig. 2-A). The thicknesses of the two materials may be chosen so that they

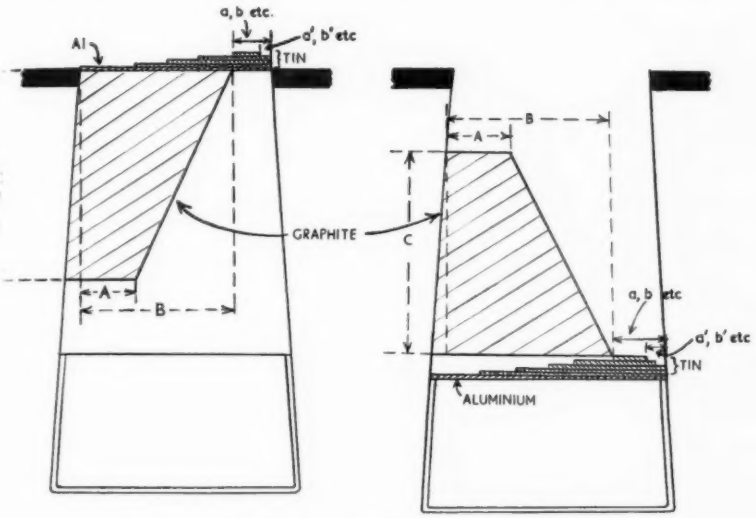

Fig. 3. Practical construction of graphite/tin wedge applicators.
(For actual dimensions, see Table p. 160.)

attenuate the radiation to an equal extent, e. g. 50 % attenuation is given by 28 mm of graphite and 0.18 mm of tin (see Diagram 1). The intensities on a phantom surface will therefore be the same on the two halves of the field, neglecting any difference in backscatter arising from the difference in quality of the two sections. Because, however, of the quality effect (as already detailed) the percentage depth doses are different on the two sides, and the isodose curves for the field as a whole will lie at an angle to the surface, although no dose variation occurs on the surface itself. This phenomenon may be termed 'quality wedging', but unfortunately the effect is not large enough to produce a wedge of sufficient slope for practical use. The thickness of the graphite block must therefore be increased in order to introduce an element of ordinary 'absorption wedging' (Fig. 2-B); this also produces a surface variation, i. e. a hot-spot, but it will be shown that this is of considerably smaller magnitude than would be obtained with a comparable copper wedge.

The incident radiation depicted in Fig. 2 is, of course, considerably softer (HVL 0.6 mm Cu) than would normally be used in deep therapy. This is because the ordinary clinical filter is, in effect, incorporated in the wedge filter. The quality of the radiation reaching the tumour region is, however, equal to, or even harder than, that obtained with a copper wedge plus 1 mm Cu clinical filter (see below).

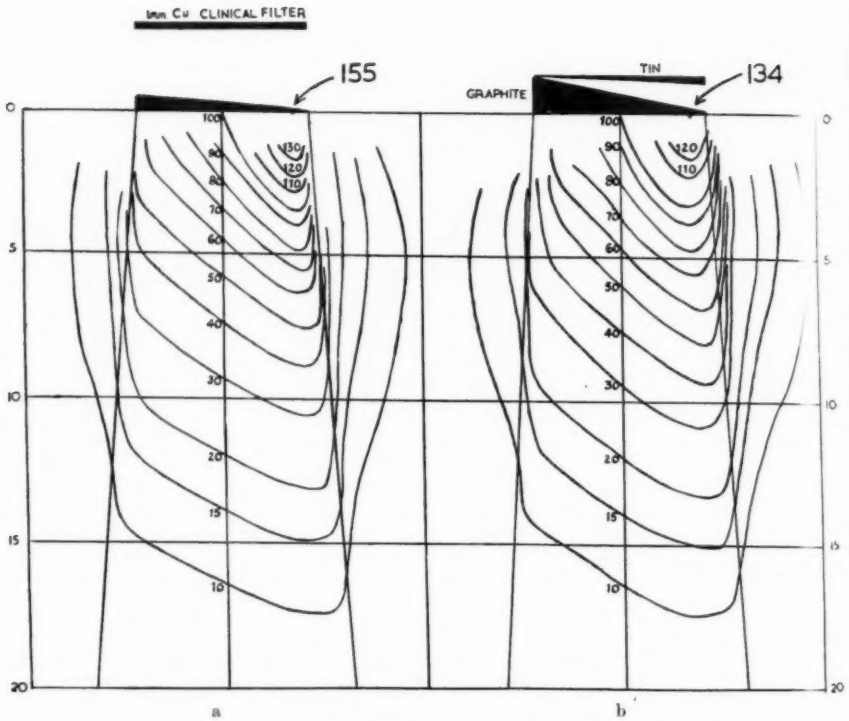

Fig. 4. Isodose charts of 6 × 8 cm wedges: a) copper, b) graphite/tin.

In practice, the graphite/tin combination takes the form of a massive graphite wedge block and an overlapping stepped 'anti-wedge' of tin (Fig. 3). The graphite wedge is machined from a block, fabricated (using 'Bostick' or similar adhesive) from the $^1/_2''$ or $^3/_4''$ (1.27 or 1.90 cm) thick plates obtained from the manufacturers, Powell Duffryn Carbon Products Ltd, Springfield Road, Hayes, Middlesex, England. (The author is grateful to Mr. Beech for his help in this matter. Strictly speaking, the material should be described as 'industrial carbon' rather than graphite, and as such has a lower bulk density than that of natural graphite (EVERETT 1958).) The type used in the present work was the hardest and densest grade available in plate form (grade EO4), its density being 1.65 gm/cm³. It is less pure, but also considerably less expensive, than, for example, the graphite used in nuclear reactors. Following the design principles evolved for copper wedges, the sloping portion of the graphite

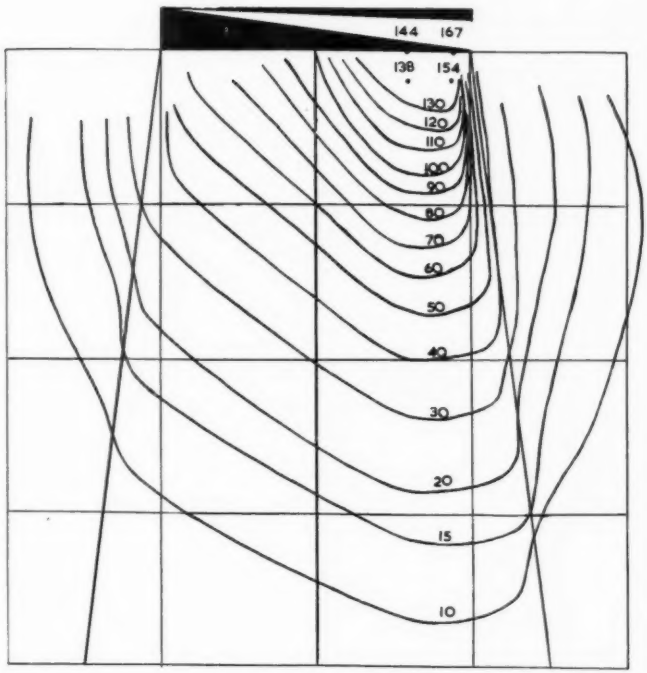

Fig. 5. Isodose chart of 10 × 15 cm graphite/tin wedge.

wedge is confined to the middle section of the field width, there being a non-sloping end section at the thick side and a blank section on the thin side. The blank section is occupied by the flat part of the tin 'anti-wedge', while the sloping section of the tin wedge is of the same width as the sloping graphite portion, but tapers in the opposite sense. Secondary filters of copper and aluminium are provided after the tin wedge.

Two practical forms of graphite/tin wedge applicators have been constructed. Both are based on standard 'Fulfield' applicators with flat perspex end plates. In type 1 (Fig. 3, left) the graphite block is inserted into the applicator cone through the back aperture and the tin wedge is fixed into the recess immediately behind. This method has the disadvantage that no screenage is provided to stop radiation scattered from the large graphite block from reaching the skin. Also, in the non-wedge direction, in which the block occupies the full length of the back aperture, it is impossible to shape the former outwards so as to fit the conical shape of the applicator. A more satisfactory method (Fig. 3,

Table

Dimensions in centimetres unless stated otherwise

Component	Symbol (Fig. 3)	Wedge, type and FSD: 5 × 7 cm Type 2 40 cm FSD	6 × 8 cm Type 1 50 cm FSD	10 × [illegible] cm Type 2 40 cm FSD
Graphite				
Minimum width	A	0.6	1.2	2.
Maximum width	B	3.5	3.2	6.
Thickness	C	8.2	6.5	8.
Tin				
Step 1. 4.5 thou[1] Sn	a′	0	0.4	1.
	a	1.3	1.0	2.
Step 2. 4.5 thou Sn	b′	0	0	0.
	b	1.7	1.6	3.
Step 3. 4.5 thou Sn	c′	0	0	0.
	c	2.1	2.4	4.
Step 4. 4.5 thou Sn	d	2.9	—	5.
Step 5. 10 thou Cu	e	3.9	3.2	7.
Step 6. 1 mm Al	f	4.7	4.2	9.

[1] 1 thou = 0.0254 mm.

right) is to remove the perspex front portion of the applicator (or, better, to order the applicator with this end uncemented), and to insert the graphite block from the front, followed by the tin wedge and its secondary filters. Finally the perspex cover is cemented into place. The resulting applicator has a focal-skin-distance a few millimetres greater than normal, but this is unimportant.

The design of a graphite/tin wedge involves the choice of suitable thicknesses of the two materials at each point across the field. As far as beam intensity is concerned, the combined filter must simulate a single wedge sloping in the same sense as the graphite component, i. e. the increasing absorption of the graphite, proceeding towards the thick side, must more than compensate for the decreasing absorption of the tin component. The hardness of the beam, however, must change in the opposite sense, but this is ensured by the tin 'anti-wedge' since the contribution of the graphite towards hardening the beam is small. As an aid to the design of the wedges, absorption curves were measured in each of the two materials, with preliminary filters of various thicknesses of the other material. Here a further advantage emerges of the second constructional method described above: whereas the absorption of graphite varies with the initial tin filtration, the absorption of tin is virtually independent of the initial graphite filtration. The design process was based on unpublished empirical data derived from copper wedges, relating

wedge isodose curves to the surface conditions (quality and intensity of the primary beam and relative backscatter at different points across the field). Final adjustments to the wedge design were made by trial and error.

Three graphite/tin wedge applicators have so far been constructed: 5 × 7 cm, 6 × 8 cm and 10 × 15 cm. Dimensional details are given in the Table on p. 160. In Fig. 4 isodose curves of the 6 × 8 cm wedge are compared with those of a copper wedge of the same dimensions. This was the first graphite/tin wedge designed; type 1 construction was used. It was anticipated that the increased efficiency of this type of wedge would raise the surface dose-rate to a sufficient extent to justify a return to 50 cm FSD applicator instead of the 40 cm used throughout for the copper wedges. In practice a higher dose-rate was judged more valuable than a longer focal-skin-distance, and for the two wedges which followed the FSD reverted to 40 cm. Fig. 4 shows that the two sets of isodose curves are almost identical. The graphite/tin wedge, however, has a considerably lower maximum surface dose. Examination of Fig. 4 also shows that the isodose lines of the graphite/tin wedge are more nearly parallel than in the copper type.

Application of graphite/tin wedges

The advantages illustrated in Fig. 4 may be exploited in two ways. In the first place, a large wedge may be constructed which combines a reasonable wedge slope with a comparatively low maximum surface dose. This has been done for the 10 × 15 cm size (Fig. 5), the slope being 41° and the maximum surface dose 167 % compared with about 240 % for a copper wedge of similar characteristics. Even this 167 % is of smaller significance than may appear at first, since, after an initial rise from the central axis the surface dose-rate remains practically constant at about 144 % until a few millimetres from the edge of the field, when it rises rapidly to 167 % in a very narrow high-dose band. This effect indicates that some further 'smoothing' in the design of this wedge could be carried out with advantage.

At the other end of the scale, a small wedge may be constructed having a very low maximum surface dose. The 5 × 7 cm graphite/tin wedge has a slope of 44° and a maximum surface dose of only 124 %. The advantage of the low maximum dose is illustrated in Fig. 6, in which combined isodose curves are shown for two wedges at right angles with a 4 cm separation and without a normal field, i. e. $\theta = 90°$, s = 4 cm, N = 0. (See part II for terminology.) The comparison is made with the 5 × 5 cm copper wedge (no 5 × 7 cm copper wedge existing) for

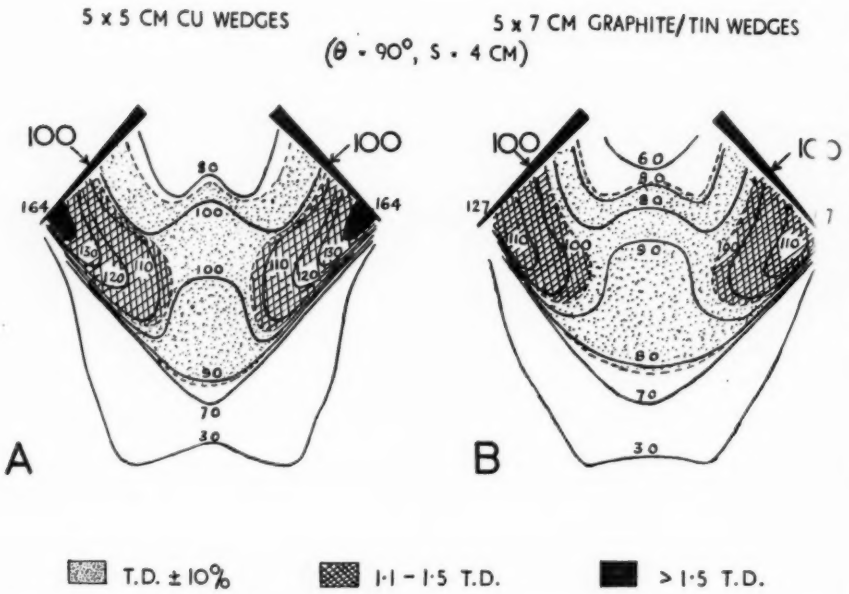

Fig. 6. Isodose charts of wedge pair at right angles, 4 cm separation: a) 5 × 5 cm copper wedges, b) 5 × 7 cm graphite/tin wedges.

which the maximum surface dose is 161 %. The arrangement is clinically unacceptable in the latter case because of the high dose regions, but is quite satisfactory using graphite/tin wedges. Indeed, in the latter case the addition of a 5 × 7 cm normal field (50 r incident dose) would reduce the hot-spot factor to about 1.1 without seriously modifying the dose distribution in the central region.

Conclusions

The *advantages* of this method of wedge construction, already mentioned, may be summarized as follows:

The maximum skin dose is considerably lower than for a copper wedge of similar isodose characteristics.

The isodose curves retain their slope more effectively at a depth.

The surface dose-rate is increased by 20—25 % at a given FSD.

ome *disadvantages* of the new wedges should also be mentioned.

hey must be used without the normal clinical filter. At the London Ho ital graphite/tin wedges are used with a clinical filter of 1 mm Al, as e sets will not operate without a filter in position. Since most modern set are equipped with filter-interlock devices, this difficulty need not be co dered a serious one.

he new wedges are more difficult to design and construct. The des n problem is mainly a question of experience — there is a great de of accumulated data on the design of copper wedges, but very little on aphite/tin. Admittedly, however, graphite is not an easy (or popular) ma rial for handling in an instrument workshop and it may be that an alt native will be found. Unfortunately unit density materials, including per ex, are unsuitable as they do not absorb sufficient radiation in a co enient thickness, 8 cm being about the practical limit to place inside an pplicator cone. Pure boron is prohibitively expensive, but a promisin alternative is boron carbide, a compound marketed under the trad name 'Norbide' abrasive, which is a powder containing approximately 78 % boron and 21 % carbon. This material has not yet been inv stigated in detail. It is intended that the powder be held inside a wed e-shaped box constructed of thin perspex.

Finally, the question of beam quality needs to be discussed. One possible objection to the new wedges is that in part of the field the radiation is soft. However, the radiation which makes the major contribution to the tumour dose is that which passes through the half of the wedge between the central axis and the thin edge. In this half the filtration ranges (in the case of the 5 × 7 cm wedge) from approximately 0.5 mm Sn + 0.25 mm Cu to 0.1 mm Sn + 0.25 mm Cu + 40 mm Cu. The corresponding half-value-layers are approximately 2.4 mm Cu at the 'nose' and 1.6 mm Cu at the central axis. The values for the 5 × 5 cm copper wedge are 1.7 mm Cu at the 'nose', 2.3 mm Cu at the central axis and 3.0 mm Cu at the thick end. At the thick end of a graphite/tin wedge the graphite filtration hardens the beam to about 1.0 mm Cu HVL.

Summarizing, it may be said that the advantages of the graphite/tin wedges are such that they merit serious consideration for replacing or supplementing copper wedges in deep roentgen therapy, especially where it is desired to use large wedge fields. The two-material principle is of general application where a heterogeneous radiation is to be wedged. Even for roentgen rays generated at 2 to 4 MV the hardening effect of lead vis-a-vis aluminium appears to be sufficient to make the method worth-while. Wedges for cobalt units will, however, be of a single material.

Acknowledgements

The author records, with pleasure, his debt to Dr. L. A. W. KEMP for many useful discussions.

SUMMARY

In a copper wedge filter the hardening of the radiation on the thick side of the wedge increases the relative depth doses on this side and therefore opposes the effect of beam attenuation in producing sloping isodose curves. This difficulty can be avoided by using a low atomic number material (e. g. graphite) on the thick side and a material of high atomic number (e. g. tin) on the thin side. The construction and properties of such wedges are described. The main advantage of a graphite/tin wedge as compared with a copper wedge producing isodose curves of similar slope, is a considerable reduction in the maximum percentage surface dose. Further advantages, some disadvantages, and applications of the method are also discussed.

ZUSAMMENFASSUNG

In einem Kupfer-Keilfilter erhöht die härtere Strahlung an der dicken Seite des Keiles die relative Tiefendosis an dieser Seite und wirkt daher dem Effekt der Strahlenabschwächung entgegen indem abfallende Isodosenkurven erzeugt werden. Diese Schwierigkeit kann durch Verwendung von Material niederer Atomzahl (z. B. Graphit) am dicken Keilende und von Material hoher Atomzahl (z. B. Zinn) am dünnen Keilende verhindert werden. Der Aufbau und die Eigenschaften solcher Keile werden beschrieben. Der Hauptvorteil eines Graphit-Zinnkeiles verglichen mit einem Kupferkeil, der ähnlich abfallende Isodosenkurven erzeugt, besteht in einer beträchtlichen Reduktion der maximalen prozentualen Oberflächendosis. Weitere Fortschritte, einige ungünstige Auswirkungen sowie die Anwendung der Methode werden besprochen.

RÉSUMÉ

Avec un filtre-en-coin en cuivre, le durcissement de la radiation du côté épais du coin augmente les doses en profondeur relatives de ce côté et s'oppose ainsi à l'effet d'atténuation du faisceau en augmentant la pente des courbes isodoses. Cette difficulté peut être évitée en utilisant un matériau de petit nombre atomique (par exemple du graphite) du côté épais et un matériau de nombre atomique élevé (par exemple de l'étain) du côté mince. L'auteur décrit la construction et les propriétés de tels coins. Le principal avantage d'un coin graphite/étain par rapport à un coin en cuivre donnant des courbes isodoses de pente semblable est une réduction considérable du pourcentage maximum de dose en surface. L'auteur examine d'autres avantages, quelques inconvénients et les applications de cette méthode.

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REPORT ON DECISIONS AT THE 1959 MEETING OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP)

Introduction

The period since the Commission's last regular meeting in 1956 has been the most active in its history. Because of rapid developments in the field of nuclear energy and the more widespread use of radiation sources of all types the scope of the work has increased beyond the field of medical radiology into all fields of radiation protection, including industrial uses as well as the exposure of the general public.

In 1955 the United Nations established a Scientific Committee on the Effects of Atomic Radiation to collect and evaluate information on radiation exposure and radiation effects. In addition, bodies such as the World Health Organization, the International Labour Office, the Food and Agriculture Organization and the International Atomic Energy Agency are actively interested in radiation protection problems and look to the International Commission on Radiological Protection for guidance. Although the primary responsibility of the Commission has been to the radiological profession, it has had to widen its scope and has accordingly been active not only during the last two international Congresses of Radiology but also in the intervening period.

Amendments to the 1953 (1) Recommendations were reported to the Mexico Congress and published in 1957 (2). Revised Recommendations of the Main Commission were adopted in 1958 and printed early in 1959 (3). Reports of the various Committees exist at present in various stages of preparation. The Report of Committee II on internal radioactive substances is already in press (4). A revised version of the Committee III Report, which is essentially a code of practice for the radiological profession, was approved during the 1959 meeting and will be published in the near future (5). The Report of Committee IV on high energy and heavy particle radiation is undergoing a final revision. Committee V has prepared a report on the disposal of radioactive waste from hospitals and laboratories and is proceeding as rapidly as possible to prepare a further report on the disposal of waste from atomic energy establishments.

The Commission has an official relationship with the World Health Organization and the International Atomic Energy Agency. There has been close co-operation with the United Nations Scientific Committee on the Effects of Atomic Radiation, and the Commission, jointly with the International Commission on Radiological Units and Measurements, has on two occasions accepted its invitation to perform special studies. The results of the first study on the evaluation of gonad dose from medical procedures were published in 1957 (6). The second study, on the evaluation of exposure relevant to somatic damage, has been initiated and a report is to be prepared before the end of 1960.

The Commission also co-operates with the International Labour Office and the Food and Agriculture Organization and has invited them to send observers to future meetings. The Commission has been invited to send observers to appropriate meetings of the International Organization for Standardization and the United Nations Educational, Scientific and Cultural Organization.

During the 1959 meeting, the Commission discussed its basic Recommendations (3) and although no substantial changes were made, a number of explanatory statements were drafted. These statements which will be presented in the following text include

su subjects as the irradiation of pregnant women, the maximum doses to individuals in e population at large, the interpretation to be placed on the paragraph dealing with th contamination of public air and water supplies, and the hours of work and vacation of diation workers.

A grant from the Rockefeller Foundation made it possible for the Commission to in e a number of non-member experts on dose-effect relations to participate in the M ich discussions and be available for consultation.

During the preparation of this statement the ICRP has had the following composition:

1956 — 1959

(Including the Munich sessions)

R. M. Sievert, Chairman (Sweden); G. Failla, Vice-Chairman (U. S. A.); W. Binks, Secretary (Great Britain) (Mr. Binks resigned as Secretary in 1957, for health reasons. After his resignation E. E. Smith (Great Britain) served as Acting Secretary, and since August 1, 1957, B. Lindell (Sweden) has served as Temporary Secretary); L. Bugnard (France); H. Holthusen (Germany); J. C. Jacobsen (Denmark); R. G. Jaeger (Germany); W. V. Mayneord (Great Britain); K. Z. Morgan (U. S. A.); R. S. Stone (U. S. A.); L. S. Taylor (U. S. A.); E. A. Watkinson (Canada); Sir Ernest Rock Carling, Chairman emeritus (Great Britain).

1959 —

(Present composition)

R. M. Sievert, Chairman (Sweden); E. E. Pochin, Vice-Chairman (Great Britain); W. Binks (Great Britain); L. Bugnard (France); H. Holthusen (Germany); J. C. Jacobsen (Denmark); R. G. Jaeger (Germany); J. F. Loutit (Great Britain); K. Z. Morgan (U. S. A.); H. J. Muller (U. S. A.); R. S. Stone (U. S. A.); L. S. Taylor (U. S. A.); E. A. Watkinson (Canada); Sir Ernest Rock Carling, Chairman emeritus (Great Britain); G. Failla, Vice-Chairman emeritus (U. S. A.); B. Lindell, Secretary (Sweden).

Explanatory statements and amendments to the 1958 Recommendations

In the 1958 (3) Recommendations all maximum permissible doses are expressed in rems without reference to the appropriate RBE values. Such reference will be given in the reports of the Committees concerning the application of the recommendations in various specified fields. The RBE values used in each of the Committee reports to be published are consistent with those published in 1954 (1).

The following statements refer to particular paragraphs in the 1958 Recommendations:

Explanatory statement of paragraph 46 (see also paragraphs 35 and 41). It has been recommended that "medical exposure" be excluded from the calculation of the maximum permissible dose of those occupationally exposed. The Commission wishes to emphasize that "medical exposure" refers to the exposure of *patients* that is necessary for medical purposes and *not* to the exposure of the personnel conducting such procedure.

Interpretation of paragraph 49 (see also paragraphs 10, 14 and 52). A calendar 13 week period may be used instead of a period of 13 consecutive weeks *if there is no reason to suppose that doses are being accumulated at grossly irregular rates.*

Addition to paragraph 49. The following words should be added at the end of the paragraph: *especially in the case of women of reproductive age.*

New paragraph to be added after paragraph 51 (e). "51 (f) Where work involves exposure to β-rays of $E_{max} > 2.5$ MeV, eye shields or other suitable shielding may be necessary to keep the dose in the lens within permissible limits. In the case of exposure to β-rays of lower energy, if the provision of such shielding is impracticable, the small additional β-ray dose in the lens over the dose already permitted for more penetrating radiations, such as γ-rays or neutrons, is permissible, provided the dose in the skin is limited to the level recommended in paragraph 52 (a)."

Additional paragraphs regarding the application of paragraphs 49, 51 (d) and 51 (e) to cases of internal exposure. With reference to paragraph 49:
"52 (e) One or more short term exposures to radioactive materials (together with any exposure to external radiation) within a period of 13 consecutive weeks is considered acceptable if the total intake of radioactive material during this period does not exceed the amount that would result from intake for 13 weeks at the maximum levels for occupational exposure to such radioactive materials permitted by the 1959 Report of Committee II. The dose to the critical organ during the following 50 years resulting from such an intake will not exceed the quarterly limit on dose stated in the 1958 Recommendations of ICRP. These limits are

(1) for the whole body and the gonads: 3 rems;

(2) for the skin, thyroid and bone: 8 rems (based on body burden of 0.1 microcurie of Ra^{226}, see Report of Committee II);

(3) for other organs: 4 rems."

With reference to paragraph 51 (d):
"52 (f) In the case of an accidental high exposure to radioactive materials where the total intake of radioactive material exceeds the amount that would result from intake for one year at the maximum levels for occupational exposure to such radioactive materials permitted by the 1959 Report of Committee II, an estimate of the intake resulting from the exposure shall be entered on the individual's record and he shall be referred to competent medical authorities for appropriate action."

With reference to paragraph 51 (e):
"52 (g) Emergency work involving exposure above permissible limits to radioactive materials shall be planned on the basis that the total intake of radioactive material during the emergency period should not exceed the amount that would result from intake for one year at the maximum levels for occupational exposure to such radioactive materials permitted by the 1959 Report of Committee II. The dose to the critical organ during the following 50 years resulting from such an intake will not exceed the maximum yearly limit on dose stated in the 1958 Recommendations of ICRP. These limits are

(1) for the whole body and the gonads: 12 rems;

(2) for the skin, thyroid and bone: 30 rems (based on body burden of 0.1 microcurie of Ra^{226}, see Report of Committee II);

(3) for other organs: 15 rems.

When such an exposure has occurred, an estimate of the intake shall be entered in the individual's record and measures shall be taken to prevent further exposure during the period of time it would take to accumulate this intake at the constant level of occupational exposure permitted by the 1959 Report of Committee II for such materials."

Explanatory statement of paragraphs 53 to 57 (see also paragraphs 15, 16, 38 and 39). The size of a "group" or a "population" is a relative concept and it is often difficult to decide whether a group should be considered "large" and whether relatively small natural

po lations should be referred to as the "whole" population with respect to exposures of ich the importance depends on the size of the group exposed. The size of a group is irr vant in the case of *individual* exposure, where groups are defined only to distinguish be en individuals for whom the recommended maximum permissible doses are different for various reasons or for whom the membership of a certain group provides for mo specific recommendations with regard to individual monitoring, medical examinations and surveys of the protection conditions. In the case of *e. g.* average exposure, ho ver, the "*whole*" *population* is involved and the responsibility for the interpretation of is concept will rest with national and international administrative authorities respo sible for the legal application of protection requirements.

Additional section regarding exposure of individual members of the population at lar (to follow after paragraph 57). A new section, under the heading "*Exposure of the po lation at large*" should be added after the section headed "*Exposure of special groups*" (pa graphs 53—57). The text to be added, referring to both external and internal exposure, reads: "The maximum total dose limit for *individuals* in the population at lar (excluding those occupationally exposed and the special groups B (a) and B (b) sho ld be that recommended for members of the special group B (c) (cf. paragraph 55)."

Correction to paragraph 65. The figure "1.7" in paragraph 65 Addendum (c) is a misprint for "0.7".

Interpretation of paragraph 68. The basis for the limits of permissible exposure of populations to man-made sources of ionizing radiations is the dose received by the various organs of the body and not the MPC-values, or other criteria by which the dose is controlled. Nevertheless, for planning purposes some guidance as given in paragraph 68 must be available. The word "average" in paragraph 68 refers to the concentration of radioactive nuclides, averaged over a year, in the total intake to the average person of the population.

Statements on items not included in the 1958 Recommendations

Occupational exposure of pregnant women. With regard to occupational exposure of pregnant women the Commission notes that: (1) It is especially in respect of somatic damage in foetal tissues that pregnant women present a "special risk problem" in case of occupational exposure; (2) Any special recommendations for pregnant women must in practice apply to all women of reproductive age.

Occupational working hours and length of vacation. The Commission considers that with the present maximum permissible exposure levels no special treatment of radiation workers with respect to working hours and length of vacation is required.

Emergency exposure of environmental populations. This subject was discussed extensively during the Munich meetings and the Commission considers that the British Report (7) recommending criteria for acceptable levels under emergency conditions of I^{131}, Sr^{89}, Sr^{90} and Cs^{137} ingested in food or milk constitutes a useful and sound approach to the subject.

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REPORT ON RECOMMENDATIONS OF THE STUDY GROUP ON THE USE OF RADIOISOTOPE TELETHERAPY UNITS AND SUPERVOLTAGE RADIATION IN RADIOTHERAPY

The Study Group, which was convened by the International Atomic Energy Agency and the World Health Organization, met in Vienna 3—5 August 1959 and held six meetings. The following report was adopted.

It was the intention of the Group to produce basic recommendations which would be of value to: 1) all authorities who carry responsibilities for radiotherapy in the treatment of cancer; 2) those who are considering the establishment of radiotherapy centres; 3) practising radiotherapists; and 4) practising radiation physicists.

The recommendations have been drawn up with a view to giving practical guidance and should be considered for this purpose rather than as a contribution to fundamental knowledge on this subject. In particular, it is thought that these recommendations may be of special value in those countries where radiotherapy is not yet firmly established.

RECOMMENDATIONS

I. The value of supervoltage radiation in the treatment of cancer in comparison with other forms of radiotherapy

It was agreed that supervoltage radiotherapy at the present time has an essential place of value in the treatment of cancer by ionizing radiations. By supervoltage is meant both gamma-ray therapy, high-voltage X-ray therapy and electron beam therapy. It was recognized that any selection of categories would be arbitrary, but it was felt, nevertheless, that the following categories would be useful for guidance.

A. *Large supervoltage units*

Large supervoltage units were defined as units working in excess of 2 MeV peak, or with equivalent gamma-ray emission, and working at a source/ or focus/tumour distance of at least 75 cm, or a source/skin distance of 60 cm as an absolute minimum. This would include both the commonly used X-ray units, Van de Graaff, linear accelerator, etc., and the kilocurie cobalt unit. It was agreed that the provision of such apparatus was essential to the best treatment of patients in any institution which was treating cancer by ionizing radiations.

B. *Intermediate units*

Intermediate units were defined as smaller cobalt units working at source/tumour distance in the range of 35—50 cm. On purely scientific grounds, it was not considered that such units should be encouraged, and the only reason for their adoption would be one of economy. In any case, it should be realized that they were scientifically not as good as the large unit.

C. *Small isotope units*

It was agreed that tele-isotope units working at a distance of 25 cm and less were of value for the treatment of certain selected sites, and it was recommended that they should be made available, either in addition to large supervoltage units, or even in the absence of large supervoltage units. These units may be specifically designed to hold either cobalt-60 or caesium-137 sources. An adequate and assured supply of caesium-137 is essential for this purpose.

D. *Electron beam or very high energy X-ray therapy*

It was agreed that electron beam therapy or very high energy X-ray therapy (for example from Betatrons and other accelerators) are of great interest and that results so far achieved demonstrate that they have a valuable place in the treatment of cancer by ionizing radiations. It was decided that at the present time it was not advisable to make a recommendation that electron beam therapy or very high energy X-ray therapy were essential for all radiotherapy centres, but it was considered that it was advisable that the larger and better equipped centres should continue to gain experience in these forms of therapy, and that such experience should be gained in a greater number of well-equipped departments.

II. Requirements as to organization and personnel for the use of supervoltage radiation

A. *Personnel*

It was agreed that supervoltage radiotherapy, in common with other forms of radiotherapy, should only be conducted by adequately trained and qualified radiotherapists.

It was agreed that an essential requirement for the proper use of supervoltage radiotherapy was the adequate supply of trained personnel in the following categories:

1. *Medical radiotherapists*

2. *Radiation physicists*

These are radiation physicists specially trained in radiotherapeutic problems. It was agreed that while it was not essential for every centre to have a full-time radiation physicist, it was essential that the services of trained radiation physicists should be readily available.

It was desirable to have in addition the following:

3. *diotherapy technicians*

t was agreed that there should be an adequate supply of trained personnel in the cat ory of radiotherapy technician. Such personnel should work as assistants to, and un the direction of radiotherapists.

4. *ysics technicians*

t was agreed that it might also be essential to have available trained personnel wo ng under the direction of the radiation physicist, who were competent to maintain the pparatus.

B. *Organization*

t was agreed that supervoltage should be considered as a part of an organized rad therapy department, and that it was undesirable that an establishment should con st of supervoltage radiation alone without a background of general radiotherapy.

t was suggested as a basis for discussion, that a radiotherapy department containing sup voltage apparatus should have at least one piece of major supervoltage equipment cap le of both fixed and rotation techniques of treatment, or
two pieces of major supervoltage equipment, one for fixed field and one for rotation;
orth voltage X-ray machines;+
one r more X-ray machines for superficial treatments;
radi m or some other sealed isotope in suitable appliances for intracavitary and interstitial treat ments; and
if po sible, provision for the use of unsealed isotopes.

It was assumed that all the basic requirements for the proper treatment of patients would be available, including clinical services, adequate X-ray diagnostic facilities and adequate biological and other laboratory facilities, such as are normally available in a well-organized hospital.

In addition, it was considered that particular emphasis should be placed on the necessity for adequate clinical records so that results of treatments may be assessed.

(i) It was agreed to define orthovoltage X-ray machines as being in the 200—400 kV range.

(ii) It was agreed that the possibilities of development of caesium units as substitutes for orthovoltage X-rays should be investigated further, as it appeared that they might provide an efficient substitute for orthovoltage X-ray units and, therefore, might well be of considerable value in areas where adequate service facilities were not available. An adequate and assured supply of caesium-137 was necessary for these units.

(iii) The group was of the opinion that in some instances intermediate sized cobalt-60 units might serve as an efficient substitute for orthovoltage machines.

III. Training of personnel

A. *Definition of adequate training*

It was agreed that the following training and qualifications would be required by the personnel suggested in section II A.

1. *Medical radiotherapists*

a. A medical qualification acceptable in the candidate's own country;

b. A minimum of two years (and preferably three) of general clinical experience including pathology;

c. A minimum of three years (or two years in the case of a candidate who would go on to take a subordinate post) at a large radiotherapy centre;

d. Adequate instruction in clinical radiotherapy as well as instruction both in the form of formal lectures and laboratory training, in radiation physics, in radio-biology and in radiological health and safety;

e. It was agreed that it was highly desirable that the course of study should lead up to an examination to determine the competence of the candidate.

2. *Radiation physicists*

a. A basic qualification in physics, granted by a university or similar institution;

b. Following this, a minimum of three years' postgraduate training in radiation physics, including practical experience in radiotherapy, including supervoltage and instruction in radiological health and safety;

c. It was agreed that it was highly desirable that the course of study should lead up to an examination to determine the competence of the candidate.

3. *Radiotherapy technicians*

A recognized school education followed by a minimum course of study of two years in a large well-equipped department of radiotherapy, during which time clinical experience would be gained. This course of study should lead to qualification after appropriate examination.

4. *Physics technicians*

It was agreed that it was not necessary to specify in detail the qualifications of the personnel to assist the radiation physicist. It was recommended, however, that there should be one person immediately available who was trained to maintain the particular apparatus in use.

B. *Facilities available for training personnel*

It was agreed that additional training in radiotherapy for persons who have already had some experience and are working in this field should be made available at larger well-equipped institutions. Such additional training would be particularly appropriate for radiotherapists who had been working in isolation or in one-man departments. In addition, radiotherapists who had recently acquired responsibility for the employment of some new type of apparatus or some new technique might need additional training in the use of such apparatus or technique.

It was suggested that such additional training should in general extend over a minimum period of six months, but that the actual length of training would vary according to the needs of each individual case.

was considered that the larger teaching centres in all countries should recognize an o igation to assist the sponsoring agencies to train individuals under this programme.

IV. Protection requirements of supervoltage therapy

his subject was not discussed in detail by the Group but it was recognized that diffe nt types of apparatus would have individual requirements as regards protection in a ordance with the recommendations of the International Commission on Radiologic Protection, and it was understood that all buildings to house supervoltage apparat s should be so constructed that the dose to which any personnel would be exposed woul be below the maximum permissible as recommended by the International Commissi n on Radiological Protection.

V. Economic aspects

I is difficult to obtain exact information on the cost per patient treatment of various types of equipment owing to the different criteria used by institutions. From the information available, it seemed that the isotope units competed favourably in cost with accelerator equipment, were operationally simpler and less costly following installation, and were therefore particularly suitable in remote areas.

VI. Possibilities of international co-operation

A. *Training programmes*

In addition to the training specified previously, the following recommendations were made:

1. *Fellowships*

Further post-graduate training of radiotherapists and radiation physicists should be made available by means of fellowships with considerable elasticity in their terms.

2. *Visits of experts*

Visits of experts should be organized to give instruction and advice in various countries.

3. *Visits of composite groups*

Consideration should be given to the organization of visits of composite groups of workers interested in the various types of radiotherapy to study techniques in different countries.

B. *Study groups*

It was recommended that study groups should be held, and the following were suggested as suitable subjects for discussion. High priority should be given to the first two subjects.

1. Dosimetry in clinical practice
2. Design of controlled clinical trials in radiotherapy
3. Apparatus and techniques — basic requirements
4. Dose time relationship
5. International standard isotope capsule
6. Late somatic radiation effects with particular reference to supervoltage radiotherapy
7. Relative biological efficiency.

C. *Exchange of information*

It was agreed that the international bibliography being compiled by IAEA should be published.

D. *Research*

It was recommended that the IAEA and the WHO should promote support and undertake research into the problems of radiation medicine as it relates to atomic energy in those fields where international co-operation is most desirable.

Examples of such fields for research are:

1. International standardization of dosimetry in clinical practice

2. Design and support of clinical trials in radiotherapy.

In regard to both of these fields, it has been recommended in this report that initial study groups should be formed.

VII. Establishment of an advisory body

It was recommended that the IAEA and the WHO should jointly or separately establish a standing committee or panel to advise on problems arising in the field of radiation medicine as it relates to atomic energy. The duties of such a body in the first instance should include consideration of, and advice on, requests for assistance in relation to the recommendations contained in section VI of this report.

Subsequently, the committee or panel would be available to tender advice on other problems which will arise in the field of radiation medicine as a whole.

VIII. Publication of the Report

It was agreed that this report should have wide circulation through governmental channels, in scientific journals, and in the form of a publication by the sponsoring agencies.

In the latter case, the working papers prepared by the scientific secretaries should be included as annexes to this report.